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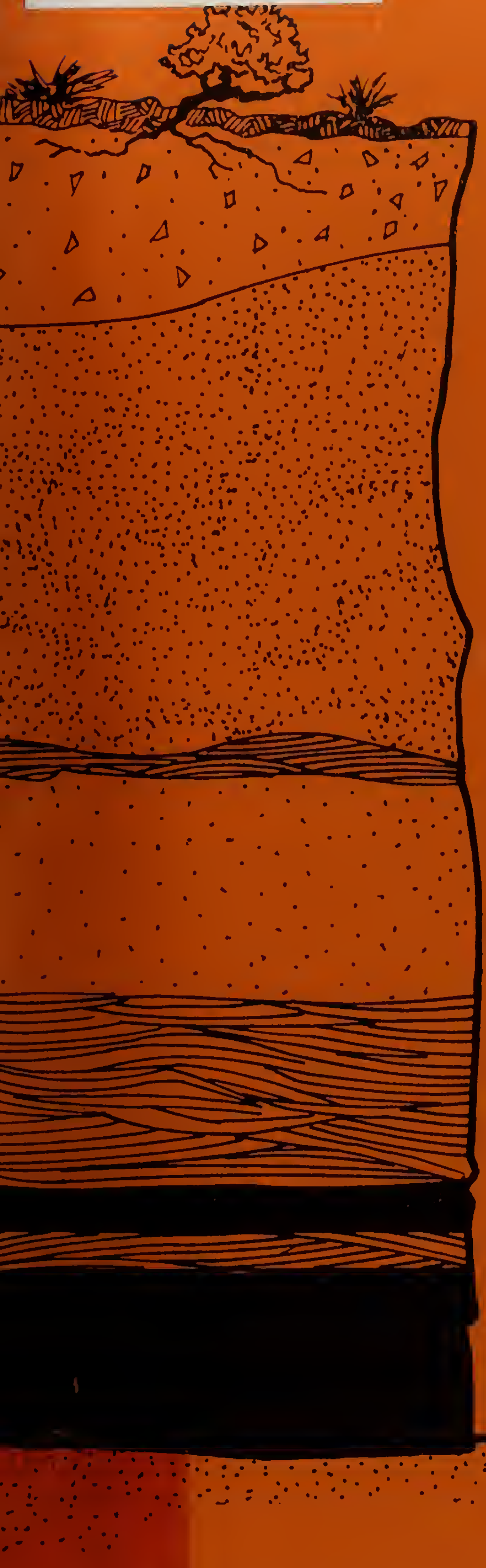
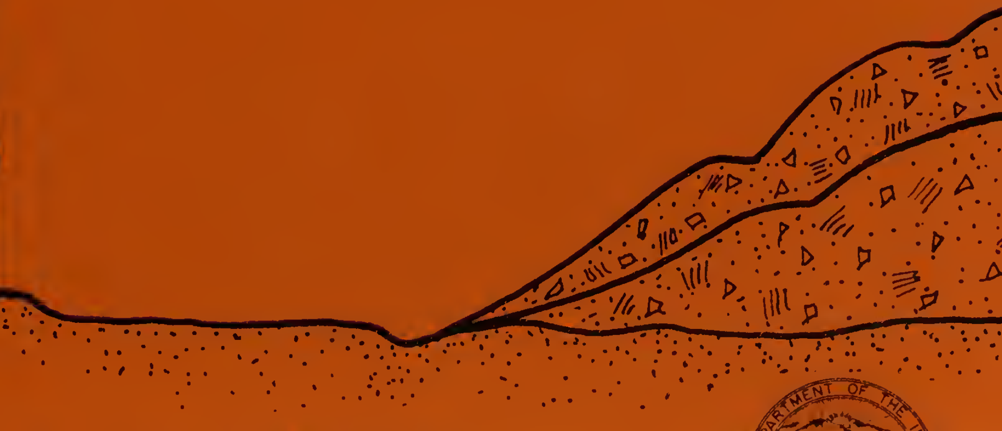


RESOURCE AND POTENTIAL RECLAMATION EVALUATION

Taylor Creek Study Site

Axial Basin Coal Field

EMRIA REPORT NO. 3-1975



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EMRIA is a coordinated approach to field data collection, analyses, and interpretation of soil, water, overburden, and energy resource data. The main objective of the effort is to assure adequate baseline data for choosing reclamation goals and establishment of lease stipulations through site-specific preplanning for surface mining and reclamation.

These reports are prepared through the efforts of the Department of the Interior, principally by the Bureau of Land Management, Bureau of Reclamation, and Geological Survey. Assistance is also provided by other Federal and State agencies.

Reports under this effort are:

EMRIA Report	Location	Source: Bureau of Land Management Offices
#1-1975	Otter Creek near Ashland, Montana	316 N. 26th Street Billings, Montana 59101
#2-1975	Hanna Basin near Hanna, Wyoming	P. O. Box 670 Rawlins, Wyoming 82301
#3-1975	Taylor Creek near Craig, Colorado	Room 700, 1600 Broadway Denver, Colorado 80202
#4-1975	Alton near Kanab, Utah	P. O. Box 11505 Salt Lake City, Utah 84111

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RESOURCE AND POTENTIAL RECLAMATION EVALUATION

TAYLOR CREEK STUDY SITE
AXIAL BASIN COAL FIELD

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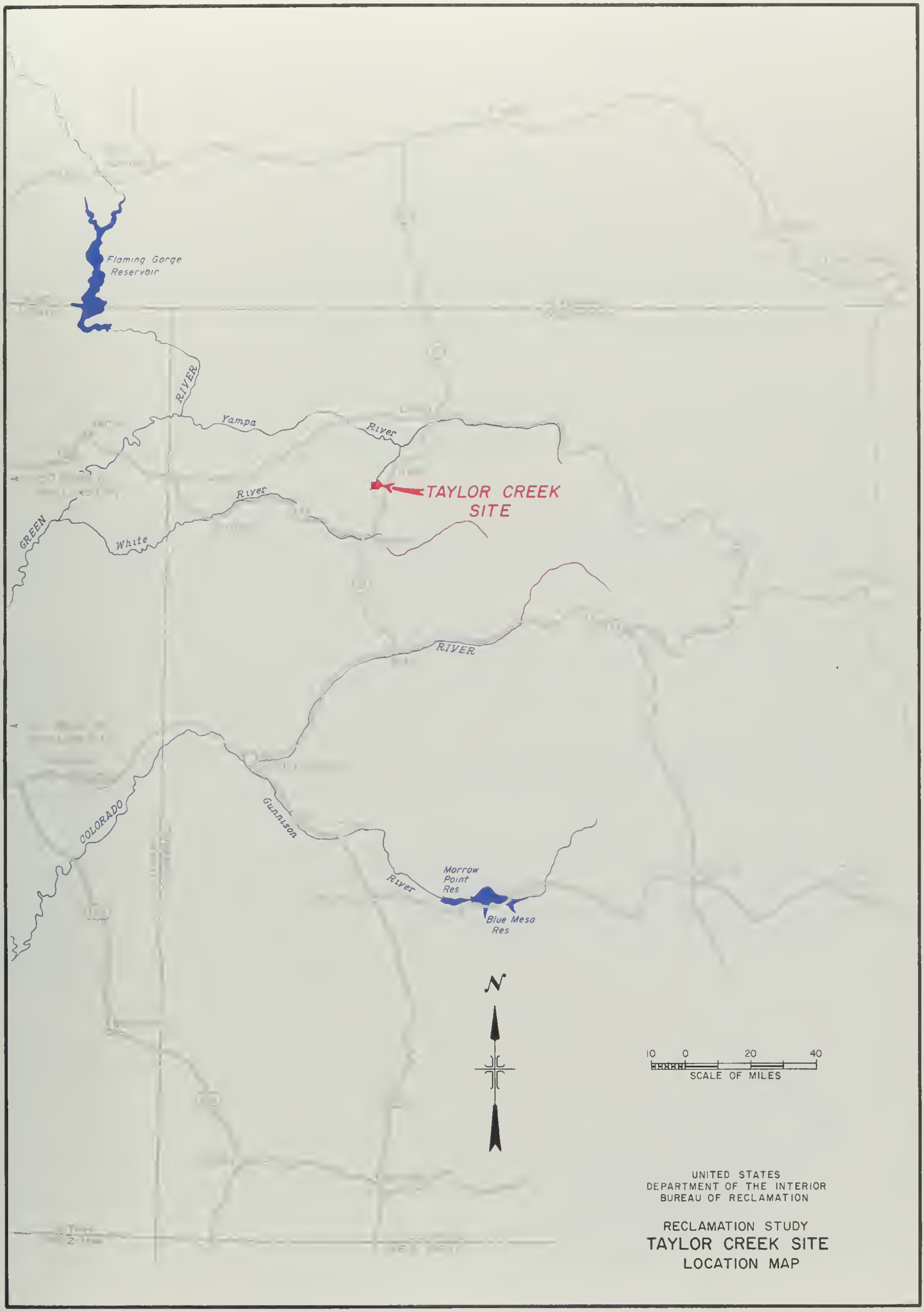
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RIVER
Yampa
River
GREEN
TAYLOR CREEK SITE
River
White
RIVER
COLORADO
Gunnison
River
Morrow Point Res
Blue Mesa Res
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SCALE OF MILES

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RECLAMATION STUDY
TAYLOR CREEK SITE
LOCATION MAP

ACKNOWLEDGEMENT

The Upper Colorado Region of the Bureau of Reclamation wishes to acknowledge and express their thanks for the help and contributions given to the finalization of this report by the many individuals, Federal and State agencies, and private interests.

A special expression of thanks is given to Mr. Pearson and his staff of the Craig District Bureau of Land Management Office, to W.R. Grace and Company personnel especially Mr. Bill Bessinger and Mr. Frank DeFillipo, and to Mr. William McTernan of VTN of Colorado.

The many sections of this report dealing with hydrology, groundwater, vegetation, etc., are contributions from the U.S. Geological Survey personnel.

Major responsibility within the Bureau of Reclamation has been exercised by the Division of Planning in Salt Lake City, Utah. Principal contributors include John McCoy and C.D. Brown. Others in the Salt Lake City Office include Paul T. Sant, Harold Furneaux, Dale Wescamp, Paul Shafer, and the Regional Drill Crew. Other contributors were Neil Bona and Phil Masterson of the Provo Office.

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SUMMARY

Introduction

This report is to present the reader with a brief, nontechnical summary of conclusions and recommendations for the detailed studies on the Taylor Creek study site. Backup data may be found in the main report.

Location and History

The Taylor Creek, Colorado, study site is located in the northwest corner of Colorado in Moffat County, approximately 22 miles south of Craig. The area is comprised of 2,280 acres of which 2,200 acres are in all or parts of secs. 2, 3, 4, 9, and 10, T. 3 N., R. 93 W. and 80 acres in sec. 33, T. 4 N., R. 93 W.

The first white settlers came into northwestern Colorado in 1830. Prior to this the Ute Indians occupied the region. The cattle industry began in 1850 when ranchers from Texas began driving their cattle through the area en route to northern ranges and markets in the California gold fields.

The railroad came to Craig from Denver in early 1900. By 1908 the town of Craig was incorporated and was entirely dependent on the livestock industry. Even though livestock raising and dry farming are still major industries in the area, the mining of coal is again gaining rapidly as a significant contributor to the economy. Coal mining coupled with oil and gas exploration and powerplant development has made the town of Craig grow from 5,000 to 6,000 in population in 1 year.

The study site was selected as a representative site of a much larger area of energy mineral lands having potential for lease and development. It is classified by the Bureau of Land Management as range land and is presently utilized for livestock grazing and wildlife management.

The Bureau of Land Management made a rather thorough archeological assessment of the area, but very little evidence of archeological remains was found.

Climate

The Taylor Creek site has a semiarid climate that is characterized by wide annual variations in temperature and well defined seasons. The area has a mean annual precipitation of 18 inches. The winters are generally cold, with large amounts of dry, light powdery snow with moderate snow water content. Summers are mild with occasional hot spells usually accompanied by dry, moderate winds.

SUMMARY

July is the hottest month of the year and temperatures will often be in the high 90's during the daytime, and mid-40's at night. The average mean summertime temperature will be in the mid-60's. January is the coldest month of the year, the average mean daily temperature will be in the mid-20's with extremes recorded as low as -40° F. to -45° F.

Records indicate 102 frost-free days in the Meeker area and 94 days in the Axial Basin area. Frost-free periods at the Taylor Creek site can be expected to be somewhat less and are estimated to be about 85 to 90 days.

Approximately 50 percent of the average annual precipitation occurs during the growing season. The snow pack normally begins to develop by late October, although September snowfalls are also common. The melt normally begins in April and continues well into June and early July.

The prevailing winds over most of the site will be from the southwest from 3 to 5 miles per hour; some 10 to 15 percent of the time the wind will blow out of the northeast. Although fair weather winds will rarely exceed 24 miles per hour, winds up to 100 miles per hour have been recorded in the area due to cold fronts and thunderstorms.

The area has a relatively low humidity, and the occurrences of fog and dew are generally confined to areas along the stream and river valleys during the winter months. Severe hail storms are rare.

Clear sunny skies with a low humidity, a high percentage of summer sunshine, summer rainfall, and heavy snow in winter are conducive to rapid vegetative growth for selected plants. From the existing data it appears that climate will not be a limiting factor in reclamation. The climate of the area is such that supplemental watering for seedling establishment and germination will not be required in most years. No known aquifer in the area would supply sufficient water, therefore, supplemental watering if employed would have to come from surface impoundments.

Geology

Geologically the area is part of the Axial Basin with the Danforth Hills to the south forming an arbitrary dividing line between the Wyoming Basin and the Colorado plateau provinces. The principal geologic formation in the area is the Mesaverde group. This group is made up of the Iles and Williams Fork Formations which contain four basic rock types: sandstone, shale, siltstone, and coal. Approximately 200 feet of the Williams Fork member were evaluated. The sandstones vary in thickness from a few feet to over 70 feet. They are light colored, white to buff. The grain size ranges from very fine to medium. Most sandstone beds contain many fine particles of clay and are usually cemented with calcium carbonate or a matrix of bentonitic clay. The shales are usually gray to

dark gray and show signs of drag folds and other flow structures. Occasionally they have black coaly zones. They range in thickness from thin lenses to massive layers many feet thick. The weathered zones are finely laminated and have many fractures near the surface. The siltstones are light colored and vary in thickness as do the sandstones. They are commonly fractured and show iron stains near the surface.

The coal occurs in seams that vary in thickness from about 1 foot to 12 feet in the area planned for surface mining. In most cases the seams contain pure coal with shaley coal in the transitional boundaries from one coal seam to another. There are thicker coal beds in this area but at greater depth than that planned for surface mining. The coal samples were not given to the Geological Survey for analysis.

Soils

The soils in the area have developed under a semiarid climate and as a result have been formed under sparce to moderate vegetative cover; therefore, they retain most of the natural fertility of the parent material.

Surface soils vary in texture, color, and depth depending upon their position. Generally they are composed of clay loam to clay with some areas of sandy loam and loam texture. Subsoils are predominantly clay. They are usually lighter in color and contain moderate amounts of lime. Soil structural development is strong, and the soil peds are distinctly visible in place, and when disturbed most of the entire mass consists of entire peds. A soil rating was made of the soils on the study site to express their suitability as a medium for revegetation.

Soil Unit II (6020) is moderately deep soils (30" to 60" or more), slightly calcareous, with a strong to moderate structural development, and nonsaline. The surface textures vary from loam to clay loam. The subsoil textures are usually fine clays. Slopes are between 3 to 5 percent. Variations in this unit are located in deep, narrow stream bottoms. The vegetation is big sagebrush, serviceberry, and oak brush with an understory of native grass and forbs. There are 234 acres in this unit, which represents 10 percent of total site area. Soils in this unit are suitable for stockpiling of topsoil.

Soil Unit III (6030) has shallow soils, 12 to 36 inches in depth, is slightly to medium calcareous, and in most cases has strong structure development. This unit is confined mostly to the sloping ridge tops or mesas and has side slopes varying from 5 to 15 percent. The surface textures are predominantly loam and clay loam, while the subsoil textures are clay loam to clay. The soils are nonsaline to slightly saline. The vegetation is big sagebrush, serviceberry, scrub oak, snowberry, and a few scattered stands of quaking aspen trees. There are 826 acres in this unit representing 36 percent of the total area. These soils are suitable for stockpiling material.

Soil Unit IV (6040) has very shallow soils, less than 12 inches, and is slightly calcareous. The structure is weak subangular blocky and nonsaline to slightly saline. The surface texture varies from loam to clay loam, while the parent material consists of weathered shale and sandstones. The slopes are 15 to 30 percent and usually have a considerable amount of rock exposed on the surface. This unit may contain some colluvial soils. The predominant vegetation is sagebrush, sparsely scattered clumps of serviceberry and Utah juniper, with stands of native grasses and forbs as an understory. There are 308 acres in this unit, which represents 14 percent of the total area. Soils of this unit do not have sufficient depth for stockpiling.

Soil Unit VI (6060) soils have been eroded away, exposing bedrock, rock ledges, and cliffs of sandstone, mudstone, or shale and have steep slopes of 60 percent or more. They have very little topsoil, and are nonsaline to slightly saline. The vegetative cover is similar to other units and may include scattered Utah juniper and native grasses and forbs. This unit represents 40 percent of the area or 913 acres and would not be suitable for stockpiling.

The soil inventory at the Taylor Creek site indicates that the soil mantle, when removed, stockpiled, and redistributed, will be a satisfactory plant-growing media. Soil Units II and III, which represent 46 percent of the area, have sufficient depth for stockpiling. This is not sufficient, however, to be redistributed over the entire study site. Soil material within the overburden must, therefore, be used to supplement the available topsoils.

Overburden Materials

Soil profile depths within the study site are generally shallow, and it is doubtful that the developed soils of the area would provide a sufficient quantity of material to act as an adequate topsoil when placed over the reformed and shaped area following mining. For this reason, it will be necessary to consider the physical and chemical properties of the overburden materials underlying the developed soils, since it is relatively certain that the more suitable of these will have to be utilized as plant growth media during reclamation operations.

Overburden material within the study site varies widely in both chemical and physical properties and, consequently, in suitability for use as plant growth media. Logs in the main report identify suitability and location of all materials evaluated.

Greenhouse studies were conducted as a check against chemical laboratory tests in the determination of overburden suitability for use as resurfacing material. In this study site, these tests verified each other. If a difference in ability to support vegetation were encountered,

additional chemical tests would have been necessary to determine those factors adversely affecting plant growth.

Vegetation

The Taylor Creek site is at the transition between the big sagebrush type in the lower portion and mountain brush in the upper. Because the site is near the upper limit of big sagebrush, sage is found on dryer sites such as south-facing slopes and fine-textured uplands. Mountain brush occupies about two-thirds of the area but is most abundant on north-facing slopes. Types of minor importance include Utah juniper on a dry, rocky bench just north of the Streeter Mine and a few stands of quaking aspen in moist valley bottoms, usually near springs.

The main grasses found in the big sagebrush type are western wheatgrass and Kentucky bluegrass. On rocky, south-facing slopes, bluebunch wheatgrass becomes an important associate.

The most common shrub in the area mapped is serviceberry and usually it is associated with Gambel's oak. Gambel's oak becomes more abundant with an increase in moisture near slope bottoms and is also found in isolated pure stands. Habitat differences cause different degrees of dominance by the three shrubs (big sagebrush, serviceberry, and Gambel's oak).

Topography

The area is a region of rolling hills, steep, small canyons, with moderately sloping flat ridge tops or mesas. The major drainage is the Yampa River. The several small tributary drainages that lie within the study site include: Wilson, Taylor, Streeter, and Good Spring Creeks. Elevations range from 7,000 to 7,600 feet above sea level. Topography of the area will influence the mining method employed.

Hydrology

Drainage basins at the Taylor Creek study site include Good Spring Creek and its tributary, Taylor Creek. Hydrologic data for determining the mean annual runoff and peak flows for these streams are extremely limited. The only streamflow records are for gaging stations established in 1974 on Wilson Creek near Axial, Colo., and Good Spring Creek at Axial, Colo. Based on the limited data, the mean annual runoff for these four streams is estimated at 2,920 acre-feet from a drainage area of 75.7 square miles.

SUMMARY

The annual peak flows for Wilson and Good Spring Creeks were estimated at 160 and 210 cubic feet per second, respectively. The estimated peak discharge for the flood with a recurrence interval of 50 years is 300 cubic feet per second for Wilson Creek and 400 cubic feet per second for Good Spring Creek. The two small tributary streams, Taylor and Streeter Creeks, are at lower elevations. Their drainages are smaller, confined almost entirely to the study area. Their peak flows will probably result from high intensity rainfall rather than from snowmelt. Peak flows for these two streams were computed from extrapolated data and are estimated on a 100-year, 1-hour rainfall. The resulting peak flow from such a storm is estimated at 100 cubic feet per second for Streeter Creek and 120 cubic feet per second for Taylor Creek. These and other hydrologic data are only estimates and must be considered as such until revised and more accurate data become available. On-going studies of these drainages are being made by the Geological Survey in 1975.

Ground water in the area is confined almost entirely to perched water on the highest impermeable beds and is commonly found at depths of less than 30 feet. It is unlikely that substantial quantities of ground water will be found at depth because the Iles and Williams Fork rocks are generally of low porosity. This is indicated by the fact that the Colorado-Wyoming mine workings at the site are dry although at a lower level than Streeter and Good Springs Creeks. Well yields from shallow sources did not exceed 5 gallons per minute during the study period.

Analyses of surface water at the site indicate nearly equal proportions of calcium, magnesium, bicarbonate, and sulfate when expressed in milliequivalents per liter. Sodium and chloride are present in significant quantities in Taylor and Streeter Creeks. The most abundant trace metals present are copper, iron, lead, and zinc. Dissolved-solids concentrations range from about 500 to 1,100 milligrams per liter. During low flow periods, the dominant cation is Mg and the major anion is SO_4. This differs from peak snowmelt periods when the dominant anion is HCO_3. Magnesium is still the major cation during snowmelt but not as large a concentration as during base flow. This may be an indication that the aquifer for this water is the coal.

Weathered bedrock and thermally altered beds have the greatest porosity and permeability. Fractured coals produce small amounts of water in the unweathered zone, but fractures are infrequent in other unweathered rocks. Shales act as aquicludes and cause small perched aquifers in the weathered zone. Unweathered sandstone and silt have low interstitial porosity and low permeability.

Effects anticipated from mining are substantial increases in sediment load and minor increases in dissolved solids in streams. Local increases in dissolved solids of ground water are anticipated. Many

small perched water deposits will be drained by surface mining. A few semiconfined aquifers of small yield capacity will be encountered by deep mining operations.

Legal Requirements

In Colorado, the surface-mined coal lands are governed by the "Colorado Open Mining Land Reclamation Act," Chapter 92, Article 13, Colorado Revised Statutes, as amended September 15, 1973. A permit, bond, and filing fee are required from mine operators. The authority for enforcement of this law is with the Executive Director of the Department of Natural Resources.

Local regulations are not as explicit regarding surface mining and reclamation as are State laws. Information to the extent and requirements of local regulations can be obtained from the Moffat County Court House at Craig, Colo.

General

Although it is assumed that the land will be returned to livestock and wildlife use following the mining, the possibility of dry land wheat production should be mentioned. If the final land shape is sufficiently leveled to permit farm machinery use and topsoil plus subsoil are restored, the area receives enough precipitation for successful dry land farming. Such use would produce more food for human consumption than is possible from native vegetation. Present alluvial bottoms and colluvial lower slopes have deep organic soils that could be used to provide a satisfactory plant growth medium.

Data collection and analyses on this study were perhaps more intensive than any prior study of this type conducted by the Bureau of Land Management. It was sufficient to point out problems and methods to minimize adverse effects on reclamation in quantitative terms. It was not, however, sufficient to develop detailed specifications or stipulations for mining and reclamation plans. The study sets the stage for potential mining companies to expand on these data in particular areas of concern. It also points out the need for the Bureau to document as accurately as possible all baseline data involving the resource values and uses which will be affected by surface mining such as:

Vegetative inventory.--i.e., composition by species, density, estimated AUM's for livestock, and estimated AUM's for wildlife.

SUMMARY

Description of uses.--i.e., class of livestock, AUM's licensed or permitted, wildlife which occupy or range in the area, recreational, instructional or educational, and other. Written and photographic documentation of significant geologic, archeologic, historic, or cultural features.

Description of watershed values.--i.e., soil surface factor and erosion classification.

Written and photographic documentation of significant geologic, archeologic, historic, or cultural features.

Conclusions

The reclamation effort will be to restore or upgrade the existing characteristics of the land and vegetative cover on the disturbed areas. Detailed studies of the soil mantle, overburden, climate, and other environmental conditions indicate that the overburden or disturbed material and other conditions are satisfactory and that reclamation of mined areas can be accomplished by following a planned program.

Where topsoils are shallow and not sufficient to provide at least a 6- to 8-inch mantle, then suitable subsurface materials should be added to attain this depth. When this occurs, it is recommended that soil amendments such as mulch and fertilizers be included to condition the surficial material.

Essentially, the requirements for removal, stockpiling, and replacement of topsoil consist of a series of earth-moving operations. The surface soils should be deposited in different stockpiles than that of the subsurface and protected from erosion. These stockpiles should be located where they will be accessible for resurfacing over the mined area as needed.

Effective shaping of the disturbed areas to a preconceived design is essential to these lands so that they blend with adjacent topography of undisturbed lands and minimize drainage problems. In the study area, it is recommended that the disturbed material be placed back in the pit and graded to a rolling-type topography with slopes not steeper than 4:1, and wherever possible they should preferably be graded to a 5:1 slope or less. Drainageways should be provided in the topographic design of the areas, and grades should be flat enough to prevent gullying and excessive channel erosion. Final grading should insure that no flat areas are created which will pond water unless temporary ponding is a part of the entire erosion control program for the area.

Recommendations for revegetation are: (1) fall seeding, preferably before October 15, appears to produce the best results in this area.

SUMMARY

Grasses and legumes should be planted as soon as possible following the seedbed preparation, (2) avoid monocultures in grass stand selection. Choose a good mix of adapted species which are drought resistant and have good sod-forming characteristics, (3) when a range mixture is used, increase the recommended rates by at least 50 percent, (4) drilling should be given first consideration for seed application, and (5) where trees are included in the revegetation process, give first consideration to transplanting mature stock rather than planting seedlings or seed.

Finally, proper post management of the reclaimed areas is essential if reclamation is to be successful. Recommendations would be: (1) post management practices as fencing to exclude overgrazing and erosion and (2) additional fertilizing when needed to maintain and insure complete establishment of adapted plant species.

The predominant species which occupy the study site include the following.

Trees:	*Utah juniper	(*Juniperus osteosperma*)
	*Quaking aspen	(*Populus tremuloides*)
Shrubs:	*Serviceberry	(*Amalanchier alnifolia*)
	Big sagebrush	(*Artemisia tridentata*)
	Douglas rabbitbrush	(*Chrysothamnus viscidiflorus*)
	*Chokecherry	(*Prunus virginiana*)
	*Gambel's oak	(*Quercus gambellii*)
	Mountain snowberry	(*Symphoricarpos oreophilus*)
Grasses:	*Western wheatgrass	(*Agropyron smithii*)
	Bluebunch wheatgrass	(*Agropyron spicatum*)
	Slender wheatgrass	(*Agropyron trachycaulum*)
	Mountain brome	(*Bromus marginatus*)
	Idaho fescue	(*Festuca idahoensis*)
	*Kentucky bluegrass	(*Poa pratensis*)
	Sandberg bluegrass	(*Poa secunda*)
	Squirreltail	(*Sitanion hystrix*)
	Green needlegrass	(*Stipa viridula*)
Forbs:	Yarrow	(*Achillea lanulosa*)
	Bedstraw	(*Galium aparine*)
	Lupine	(*Lupinus* sp.)
	Dandelion	(*Taraxicum offecinale*)
	Mules-ears	(*Wyethia amplexicaulis*)

---

*Designates those species that should be considered when establishing revegetation, seeding formulas, or transplant stock. These should not be considered inclusive.

SUMMARY

Shrubs and some trees retain their palatability level longer in the fall and winter than do forbs and grasses; also shrub cover offers wildlife and livestock protection from weather and predators. Reclamation efforts should be directed toward the development and self-perpetuation of plant communities. Shrubs produce more extensive root systems than most other plant forms and can adsorb moisture from a large volume of soil. Shrub and tree species should be chosen because of their natural adaptation to soil and climatic conditions and ultimately provide cover, soil stabilization, and nutritional browse for wildlife and domestic livestock. The native species listed have done well under the existing environment and should be given first consideration.

To enhance vegetative growth of shrubs and trees, select low pockets where moisture can accumulate during the wet seasons. The trees should be planted to a predetermined pattern or grouping, then seeded with a mixture of perennial grasses. A study conducted by Montana State University found that a monoculture of shrubs is unrealistic in reclamation; however, the seeding rate of grasses should be kept low enough to provide a moderate level of competition with shrubs, forbs, and trees. This is important since shrubs and trees compete with other vegetation for plant food.

Studies at Montana State University also indicate that placing a piece of black plastic, about 6 feet in diameter, around each tree aided in its reestablishment. After the plastic was placed and heeled in, it left a 4-foot-diameter apron to adsorb heat and reduce soil moisture evaporation. Thus the warming of the soil within the root zone may stimulate root hair development so that roots may better adsorb soil moisture to supply the needs of the developing tree.

A technique used in other surface-mined areas is to assign the front-end loader the extra duty of salvaging rootpods of native shrubs and trees from the mine area and transplanting them at predesignated locations on the reclaimed area. The advantages are many: (1) increased resistance to rodent activity, (2) drought, (3) desiccation, (4) sunscald, and (5) also accelerated the reestablishment of aesthetic values. When moving these rootpods, they should be kept as moist as possible, moved fast, and replanted to insure that the roothairs are not exposed to the wind or sun.

In removing vegetative material preparatory to mining, every effort should be made to select healthy tree and shrub species for use at transplant stock for revegetating areas previously mined. Other remaining vegetation should be chipped or mulched and incorporated into the stockpiled topsoil material.

All reclaimed areas must be protected from grazing animals for a period of no less than 3 years or until the district manager determines that the planted vegetation is sufficiently developed and established to withstand grazing use without damaging the overall vegetative cover. In

the event noxious weeds invade the rehabilitation site, the local manager should use acceptable methods of control to remove them from the plantings before desirable range plants are "crowded out" of the reclaimed area.

One of the primary factors to be considered in the manipulation of overburden materials is the proper disposition of any toxic materials encountered. The placement of these materials should be no less than 4 feet below the anticipated effective root depth of the reestablished vegetation.

Due to the climatic and edaphic conditions that prevail within the study area, it is recommended that soil amendments and surface manipulations be employed on all disturbed surfaces.

Erosion may be a problem. Data indicate that these soils should be protected by surface treatments such as contour furrowing. Infiltration rates are high enough to limit runoff and erosion damage from low intensity storms, but high intensity storms can be expected in this area. Compaction of these soils would decrease infiltration rates and increase runoff, which would result in increased erosion.

> _Mulches._--First consideration should be given to the use of grass hay applied at the rate of 5,000 pounds per acre. Second choice would be grain straws applied at the rate of 6,000 pounds per acre. Vegetative material should be blended into the soil by rotovation, disking, etc., to maximize the value of mulching, rather than left on the surface. Gravel or crushed rock can be used as a surface mulching material in stabilizing the surface against wind erosion.
>
> _Fertilization._--Greenhouse studies verified chemical analysis which indicates that all overburden samples have a plant available phosphorus and nitrogen deficiency.
>
> It is recommended that triple super phosphate fertilizer be applied at a minimum plant available rate of 50 pounds per acre. Nitrogen* should be applied at the minimum plant available rate of 40 pounds per acre.
>
> _Surface manipulation._--It is recommended that surface manipulation such as gouging, ripping, contour furrowing, pitting, chiseling, etc., be employed to maximize the availability of precipitation for plant use and also retard surface erosion. Heavy equipment used in the backfilling, grading, and shaping

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*Use Urea nitrogen when possible to get a slow release during the growing season. Fertilizers should be applied at the same time or in conjunction with the mulching so that they can be blended into the surficial materials by rotovation, disking, etc.

operations has a tendency to cause compaction of surficial materials. The above described practices will also assist in breaking up and roughening these surfaces to decrease runoff and increase water intake.

Where highly pulverized overburden materials are to be used at the surface, it is important to avoid undue compaction caused by machinery operation. If compaction does occur, it will be necessary to scarify the surface by ripping or chiseling in order to reestablish proper physical conditions for plant growth.

Chemical analyses of soils and greenhouse studies indicate that there are little if any toxic materials of any consequence in the topsoils in the Taylor Creek site. There should be little need for supplemental irrigation with normal rainfall, fall seeding, and proper plant selection.

Properly designed control structures and ditch systems will prevent adverse off-site effects from sediments and dissolved solids originating from disturbed areas.

CONTENTS

Page

I Introduction 1
  Purpose 1
  Objectives. 1
  Authority 2
  Responsibility. 2
    Bureau of Land Management. 2
    Bureau of Reclamation. 2
    Geological Survey. 3
II General description. 4
  Location and history. 4
  Climate 6
  Temperature 8
  Precipitation 8
  Other climatic characteristics. 9
    Wind 9
    Humidity and hail frequency. 9
    Frost hazards. 9
  Effect weather will have on site reclamation. 9
III Physical profile 10
  General description of main topographic features. 10
  Geology 11
    Regional geology 11
    Site geology 14
    Structure. 14
    Technique, procedures, and standards used in geologic studies 17
  Soils 23
    General characteristics. 23
    Description of natural soil bodies 23
      Ridge top soils 23
      Side slope soils. 25
      Creek bottoms or valley lands 26
    Soil inventory 26
      Results 29
      Description of soil units 29
        Soil Unit II 29
        Soil Unit III. 32
        Soil Unit IV 32
        Soil Unit VI 37
      Present use and evaluation. 42
    Laboratory and greenhouse results. 47
    Potential plant growing material 50
      Soil. 50
      Overburden. 50
    Techniques, procedures, and standards. 51
      Field procedures. 51
      Laboratory procedures 53

CONTENTS (Continued)

Page

III Physical profile (continued)
  Vegetation, soil-moisture-retention characteristics, and soil erodibility. 53
    Vegetation 53
    General soil considerations. 57
    Summary and inferences from the data 59
    Potential species for revegetation 59
  Study-site hydrology and water supply 61
    Surface water. 61
      Estimated annual runoff and peak flows. 61
      Quality 66
      Downstream dissolved-solids variations. 67
      Seasonal chemical variations. 67
      Trace elements. 68
      Stream biota. 68
      Further research needed 68
    Subsurface waters. 68
      Geology of the coal-bearing formations. 68
      Thermally altered beds. 70
      Aquifer characteristics 70
      Depth-to-water. 71
    Sediment yield 72
    Potential supply for reclamation and rehabilitation 76
IV Legal requirements on mine land reclamation. 77
  State regulations 77
  Local (county) regulations. 77
V Effects of mining on area hydrology. 79
  Potential effects on surface and subsurface water supplies. 79
    Surface mining 79
    Underground mining 79
  Drainage and pollution hazards that could occur 79
    Surface mining 79
    Underground mining 80
  Conclusions 81
References. 85

Appendix A
Appendix B
Appendix C
Appendix D

TABLES

Number		Page
II-1	Summary of climatological data	7
II-2	Summary of climatological data (Axial Basin)	8
III-1	Soil unit acreage summary	29
III-2	Vegetation-soil description TP-IX	30
III-3	Analysis of soils TP-9	31
III-4	Vegetation-soil description TP-II	33
III-5	Analysis of soils TP-2	34
III-6	Vegetation-soil description TP-VIII	35
III-7	Analysis of soils TP-8	36
III-8	Vegetation-soil description TP-I	38
III-9	Analysis of soils TP-1	39
III-10	Vegetation-soil description TP-V	40
III-11	Analysis of soils TP-5	41
III-12	Interpretive ratings for selected soil properties and qualities	43
III-13	Engineering properties of soils (measurements and interpretations)	44
III-14	Interpretive ratings for soil uses	45
III-15	Watershed management (measurements and interpretations)	46
III-16	Greenhouse data for Colorado site	48
III-17	Weathering tests, core samples from Craig, Colo.	49
III-18	Soil chemical properties	54
III-19	Percentage aerial cover, mulch, bare, and rock for the vegetation types sampled on the Taylor Creek study site	56
III-20	Horizon and profile averages of hydrologic data for soils of the Taylor Creek study site	60
III-21	Drainage basin areas and annual water-balance estimates	64
III-22	Sediment yields for selected drainage basins on the Taylor Creek study site	74
III-24	PSIAC estimates of annual source-area sediment yields from presumed overburden areas before, during, and after reclamation on the Taylor Creek study site	75

MAPS AND FIGURES

Number		Page
	Taylor Creek site location map	frontispiece
	Taylor Creek site, Colorado, general location	5
III-1	Taylor Creek site topography	12
III-2	Generalized columnar section of exposed rocks in parts of Routt and Moffat Counties, Colorado	13
	Geologic formations, Axial Basin	15

MAPS AND FIGURES (Continued)

Number		Page
III-3	Streeter Mine location, graphic section of coal beds measured in the Axial Basin	16
III-4	Geologic log of drill hole No. BR-101	18-20
III-5	Geologic log of drill hole No. BR-102	21-22
	Soil unit classification map.	27
III-6	Vegetation map of the Taylor Creek EMRIA study site, Colorado, 1974.	55
III-7	A typical soil-moisture characteristic for a soil	58
III-8	Index map of streams and sampling sites	63
III-9	Annual source-area sediment yields and channel conditions for the Taylor Creek study site, Colorado	73

I

INTRODUCTION

A growing and affluent society is creating an ever increasing need for energy. Attention has focused on the energy fuels and sources existent in the Western States, primarily the Rocky Mountain and the Northern Great Plains Coal Provinces due to the abundance, simplicity of extraction, and the high quality of the resources present.

It is the responsibility of the Bureau of Land Management to encourage and assist in meeting these energy demands and at the same time provide sound reclamation and rehabilitation guidelines so that the land subjected to disturbance is returned to a productive and useful state.

Purpose

The main purpose of this study is to assure adequate base line data for choosing optimum reclamation and rehabilitation objectives and for establishing appropriate data and interpretations for preparation of lease stipulations through site-specific preplanning of mining and reclamation.

Objectives

1. To analyze and quantify environmental impacts from surface mining of energy minerals (Colorado, Montana, New Mexico, North Dakota, Utah, and Wyoming).

2. To provide resource and impact information to the leasing site selection procedures as set forth by the Secretary.

3. To provide environmental resource information needed to implement effective reclamation and rehabilitation programs and for the development of meaningful lease stipulations as required by the mined land reclamation program.

4. To provide resource and impact information to support State and local regional development and land use planning efforts.

5. To determine the present and potential capability of the surface soil and subsurface resources to produce and maintain vegetation on known energy fuel deposits.

6. To provide physical and chemical data from which realistic stipulations may be prepared for energy mineral exploration, mining, and reclamation plans.

7. To provide data needed in the preparation of environmental impact statements, environmental analysis records, and to aid in the review of mining and reclamation plans for proposed land disturbing activities in the vicinity of the study.

Authority

Public Land Administration Act of July 14, 1969 (74 Stat. 506).

Responsibility

Bureau of Land Management

1. Select reclamation study site areas for coordinated investigation of vegetation, soil geological structure, surface water, and ground water.

2. Acts as Contracting Officer in the coordination, establishment, and execution of work orders.

3. Reviews and consolidates work order and field office data and prepares input to reports published by the Bureau of Reclamation.

4. Procurement of easements and rights-of-way to conduct the studies.

5. Distributes technical data, reports, and reclamation and rehabilitation recommendations to the Bureau of Land Management field offices.

Bureau of Reclamation

1. Conducts soil investigations.

2. Conducts drilling operations for the procurement of core samples to be used for the analysis of geological strata in overburden materials.

3. Installs casing in holes selected for ground water observation wells.

4. Characterizes and interprets, principally for revegetation, overburden materials as well as substrata immediately below the coal resources.

5. Conducts weathering tests of core samples to determine stability of overburden materials.

6. Advises and recommends suitable plant species for use in areas to be reclaimed.

7. Advises and recommends reclamation techniques.

8. Prepares a geologic map.

Geological Survey

1. Conducts vegetation and soil studies which will result in vegetation maps and related soil characteristics.

2. Assesses reclamation potential based on water available from precipitation.

3. Prepares sediment yield maps.

4. Prepares erodibility maps.

5. Makes an assessment of present ground water situation and develops projected hydrologic impacts on the assumption that area will be mined.

6. Ground water chemistry.

II

GENERAL DESCRIPTION

Location and History

The Taylor Creek site is located in the northwest corner of the State of Colorado in Moffat County approximately 22 miles south of Craig and is illustrated in the map on the following page. The area is comprised of 2,280 acres of which 2,200 acres are in all or parts of secs. 2, 3, 4, 9, and 10, T. 3 N., R. 93 W. and 80 acres in sec. 33, T. 4 N., R. 93 W.

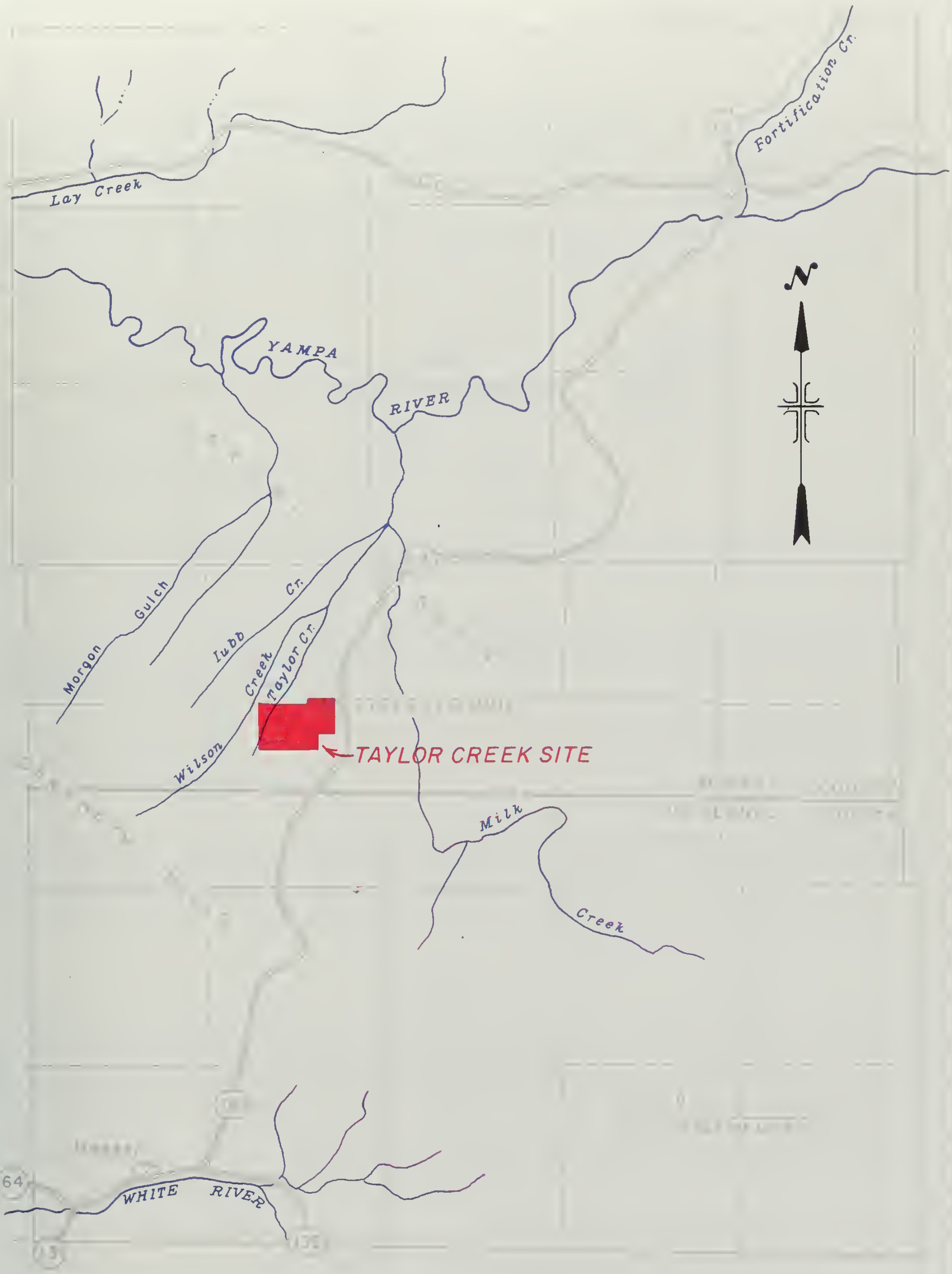
Prior to frontier settlement, this area was occupied by the Ute Indians. Fur trappers were the first settlers to come into the area in the 1830's. The Indians who were very friendly to the early settlers encouraged more to come.

The cattle industry began in the 1850's when ranchers from Texas began driving their cattle through the area en route to northern ranges and markets in the California gold fields.

In the early 1900's the railroad came to Craig from Denver. Craig was incorporated in 1908 and was entirely dependent at that time on the livestock industry. Even though raising of livestock is still a major industry in this area, the mining of coal has been and is again gaining rapidly as a significant contributor to the economy. Recent emphasis on coal mining coupled with oil and gas exploration and powerplant development has seen the town of Craig grow from 5,000 to 6,000 residents in 1 year. Recent predictions indicate Craig's population will double in the next 3 years.

The study area is classified as range land and is totally allocated for livestock grazing and the management of wildlife habitat. The more dominant vegetative cover consists of the following.

Sagebrush	*Artemesia tridentata*
Oak	*Quercus gambelii*
Serviceberry	*Amelanchier alnifolia*
Snowberry	*Symphoricarpos oreophilus*
Juniper	*Juniperous osteosperma*
Aspen	*Populus tremuloides*
Western wheat grass	*Agropyron suithii*
Wild rye	*Elymus cinereus*
Indian rice grass	*Oryzopsis hymenodies*
Idaho fescue	*Testuca idahoensis*


Lay Creek
Fortification Cr.
N
YAMPA
RIVER
Morgon Gulch
Iubb Cr.
Wilson Creek
Taylor Cr.
TAYLOR CREEK SITE
Milk Creek
64
WHITE RIVER
13
132

TAYLOR CREEK SITE
COLORADO
GENERAL LOCATION

The predominant game species that occupy the area are elk, mule deer, sage grouse, cottontail rabbits, and sharptail grouse. Elk signs have been found on the site, but it is believed that rather than reside there they use the area as a migratory corridor en route to their summer range in the Danforth Hills to the south. Well worn trails and large accumulations of droppings around watering holes indicate that mule deer reside in the area year round. Primary nongame species include mammals, birds, and reptiles as shown below.

Mammals	Birds	Reptiles
Coyote	Marsh hawks	Lizards
Bobcat	Red tailed hawk	Snakes
Weasels	Peregrine falcon*	Salamanders
Jackrabbits	Magpie	
Various rodents	Turkey vultures	

*Officially listed as endangered.

Since no permanent water supplies exist within the study area, perennial fish populations are absent.

A rather thorough archeological assessment by the Bureau of Land Management has been conducted on the project site. Very little evidence of archeological remains was found.

Surface ownership is private with the exception of approximately 100 acres of National resource lands. Subsurface coal resources have been leased to Colowyo Coal Company.

Recreational use on the area is confined almost entirely to big-game hunting of elk and deer. The region west of the study site is one of the most popular deer hunting areas in Colorado.

Climate

The Taylor Creek site is situated in the northwest corner of Colorado on the northern slopes of the Danforth Hills. The area, with an annual precipitation range of from 13 to 18 inches, has a continental climate characterized by wide annual variations in temperature and by well defined seasons. The winters are generally cold, with large amounts of dry light powdery snow. Summers are mild even though an occasional hot spell is usually accompanied by dry, moderate winds.

There is no existing weather station at the Taylor Creek site. The climatological data summarized in Table II-1 were taken from U.S. Weather Bureau records from stations in the surrounding area and characterize climatic conditions at the site. Elevations at the site range from 7,000 to 7,600 feet above sea level.

Table II-1
Summary of climatological data
Taylor Creek study site, Colorado

Station	Elevation above sea level	Precipitation (inches)		Temperature (° F.)			Number of days over 90° F.	Frost-free period (number of days over 32° F.)
		Mean annual	Average summer	Mean annual	Extremes			
					High	Low		
Craig, Colo.	6,197	13.3	3.1	42.4	99	-45	11	100
Meeker, Colo.	6,378	16.8	4.6	44.3	100	-43	13	102
Hayden, Colo.	6,336	16.5	3.5		100	-41	11	88

Temperature

July is the hottest month of the year, and temperatures will often be in the high 90's during the daytime and mid-40's at night. The average mean summertime temperature will be in the mid-60's. January is the coldest month of the year, the average mean daily temperature will be in the mid-20's, with extremes recorded as low as -45° F.

Precipitation

Approximately one-half of the average annual precipitation of 18 inches occurs during the growing season. An estimated 70 percent of the snow falls at night in the Williams Fork Basin; and because of the high dry atmosphere this snow is of the dry, light powder variety, building up tremendous depths with only moderate amounts of moisture content. The snow pack normally begins to develop by late October, although September snowfalls are also common. The snowmelt normally begins in April and continues well into June and early July. Table II-2 is a summary of the climatological data for the Axial Basin, located near the Taylor Creek study site, and was developed by the Bureau of Reclamation for its Yellow Jacket Project investigations.

Table II-2
Summary of climatological data[1]
Axial Basin[2]

Month	Average temperature (° F.)	Total precipitation (inches)
January	16.8	1.34
February	22.1	1.37
March	29.2	1.81
April	42.3	1.74
May	51.8	1.60
June	59.8	1.22
July	66.8	1.21
August	64.8	1.32
September	56.6	1.62
October	46.2	1.24
November	31.5	1.34
December	21.9	1.60
Total mean	42.5	17.41

[1] Bureau of Reclamation, Yellow Jacket Project, based on 1948-65 data.

[2] Days above 90° F. = 13.
Frost-free period (days between 32° F.) = 94.
Growing season (days between 28° F.) = 128.

Other Climatic Characteristics

Wind

Air masses tend to flow similarly to liquids, and the configuration of the mountains and valleys tends to impede the flow of faster moving air masses at higher elevations. The movement of these air masses is gently upvalley during the daytime, created by the heating of the valley floor and side surfaces, then gently downvalley in the evenings as these surfaces cool.

The prevailing winds over most of the site will be from the southwest from 3 to 5 miles per hour; some 10 to 15 percent of the time the wind will blow out of the northeast. Winds of up to 100 miles per hour have been recorded in the area due to cold fronts and thunderstorms moving through. Fair weather winds will, however, rarely exceed 24 miles per hour.

Humidity and hail frequency

The area has a relatively low humidity, and the occurrences of fog and dew are generally confined to areas along the stream and river valleys during the winter months. Severe hail storms are rare.

Frost hazards

Records indicate the frost-free period (average days above 32° F.) is 102 days in the Meeker area and 94 days in the Milk Creek or Axial Basin area. The frost-free period at the Taylor Creek site can be expected to be somewhat less and is estimated to be about 85 to 90 consecutive days. The growing season (average consecutive days above 28° F.) is estimated between 100 and 120 days.

Effect Weather Will Have on Site Reclamation

Data on the effect of weather on reclamation at the Taylor Creek site are limited. Present conditions and observations at similar locations within the area indicate that the climate will have little adverse effect on reestablishing vegetative cover. The climatic conditions of clear skies, low humidity, high percentage of summer sunshine, and frequent summer showers are all conducive to the establishment and rapid growth of adapted plant species.

III

PHYSICAL PROFILE

General Description of Main Topographic Features

The Taylor Creek study site is located on the south flank of the Axial Basin uplift, which forms the southern portion of the Wyoming Basin physiographic province. This area is typified by rather high plateaus and mesas, isolated mountain ranges, and steep mountain slopes. The specific area is characterized by gentle, north-sloping mesas with elevations ranging from about 7,000 to 7,600 feet above sea level. The area is a region of rolling hills, and the general topography varies from steep canyons and gullies to gentle sloping mesas. The major drainage is the Yampa River which enters the Green River near the Utah and Colorado State line. The Yampa River has several subdrainages that lie within the limits of the study site. Taylor Creek, Wilson Creek, Good Springs Creek, and Streeter Creek are the main drainages. Other smaller drainage courses and intermittent streams have cut through the area giving rise to the rolling topography.

View looking down Taylor Creek showing vegetation and rolling topography.

Mountains to the north, east, and south are characterized by steep bluffs and cliffs. The geology of this area is complex, said to span a

geologic period of over 600 million years, and extensive areas are favorable for the formation and entrapment of oil and gas, as well as coal beds lying near the surface.

There are a few scattered cattle ranches and dry farms in the hills; however, settlements are largely concentrated along the Yampa River.

The principal agricultural lands are along the Yampa River and its tributaries. The foothills adjoining the river and creeks are dry farmed. The mountain areas provide good forage for the grazing of livestock. A map showing the topography of the Taylor Creek site is shown on Figure III-1.

Geology

Regional geology

The study area is located on the south flank of the asymmetrical Axial Basin anticline in the southern part of the Wyoming Basin physiographic province of the Rocky Mountain system.

The most conspicuous land form in the area is the more or less continuous escarpment surrounding the broad, relatively low depression known as Axial Basin. The sandstones that form this escarpment once formed a complete arch over the basin. Erosion gradually wore them away leaving only the prominent cliffs surrounding the basin. The axis of this anticline extends from Juniper Mountain dome, near the northwest corner of the Axial quadrangle southeastward to the south side of the Monument Butte quadrangle. In general the axis of the anticline tends N. 60° W., with the geologic units dipping steeper on the south than on the north.

Two well incised subparallel streams, Taylor Creek and Good Spring Creek, traverse the study area in a northly direction flowing normally to the regional strike of the geologic units.

Rocks in the study area are sedimentary in origin. Exposed sequences near the eastern edge of Axial Basin are 13,500 feet thick. The exposed rock is of late Cretaceous and Tertiary Ages and includes thick formations of shale, sandstone, mudstone, and coal with gradational contacts common. A generalized columnar section of these sedimentary rocks is shown on Figure III-2 (Plate 18 U.S.G.S. Bulletin 1027).

Exposed rocks in the study site consist almost entirely of Cretaceous Age formations. The Mancos shale formation underlies the study area at depth and is exposed in the low depression known as Axial Basin. It is about 4,900 feet thick and, where exposed, consists of a gray to dark gray marine shale. Several thin-bedded, silty-tan sandstone, some interbedded sandy shale, and shale units are included in the uppermost part of the

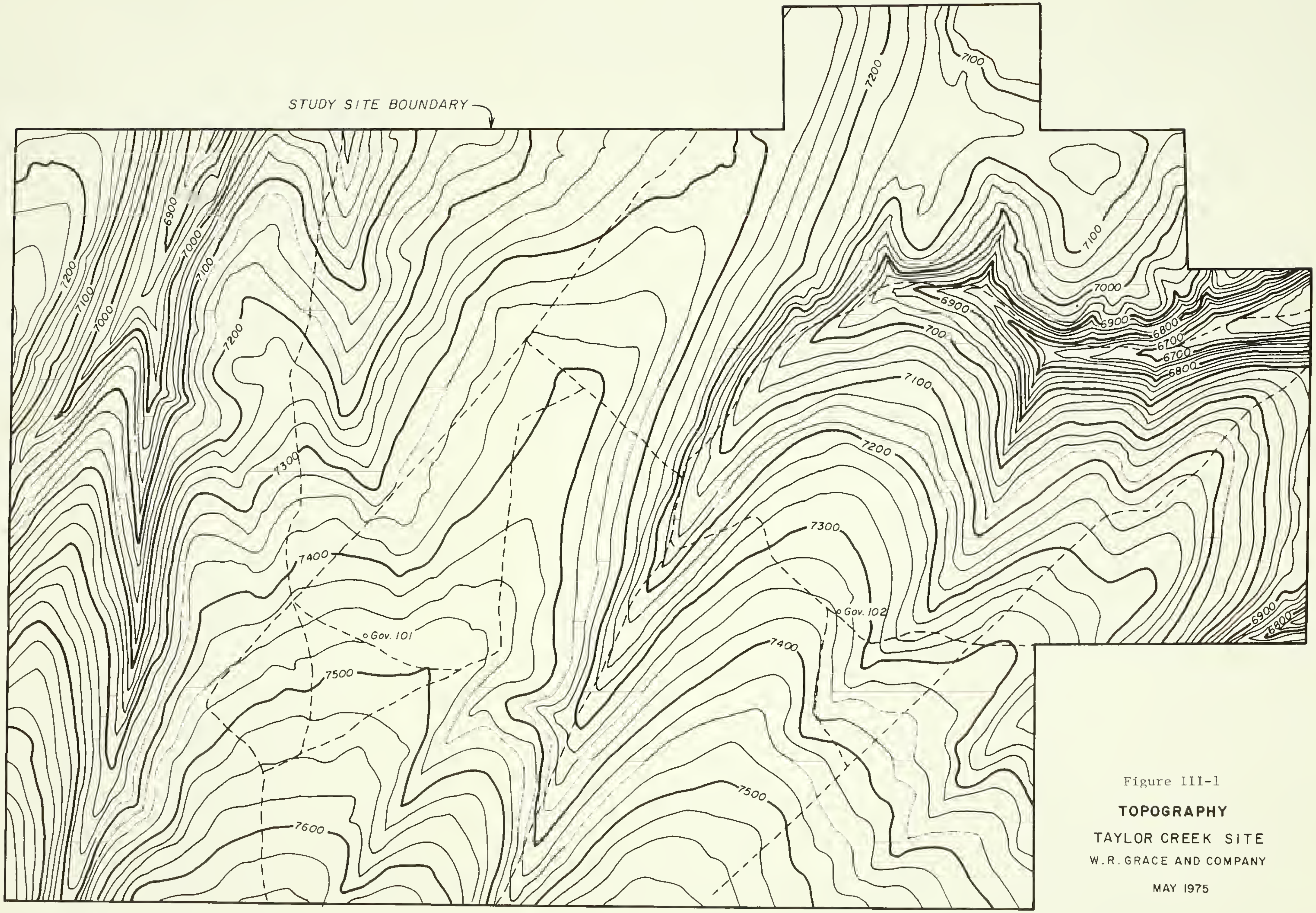

STUDY SITE BOUNDARY
7100
7200
6900
7000
7100
7200
7100
7000
7200
7300
7400
o Gov. 101
7500
7600
7100
7000
6900
6900
6800
6700
6700
6800
700
7100
7200
7300
o Gov. 102
7400
7500
6900
6800

Figure III-1

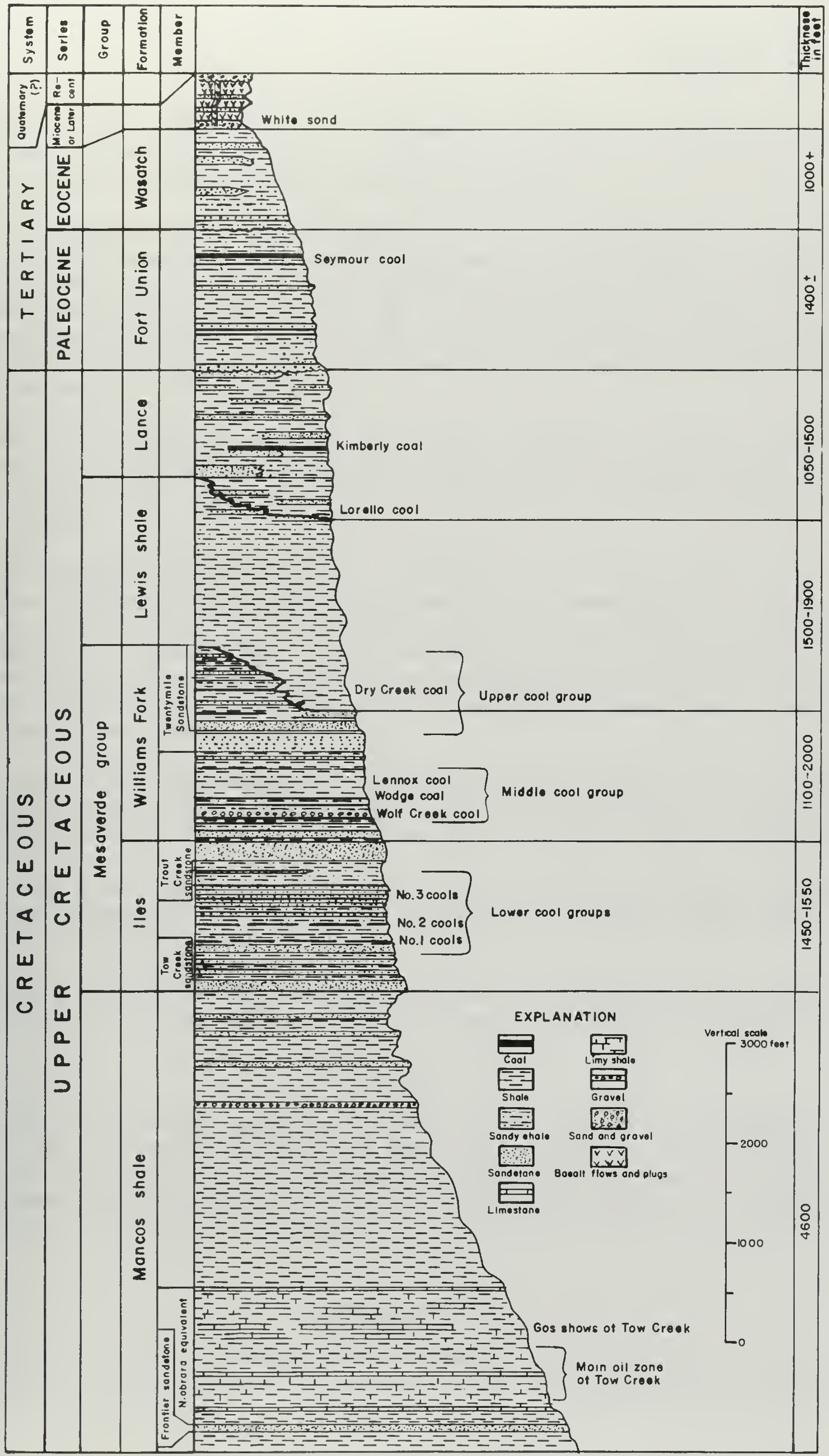
TOPOGRAPHY

TAYLOR CREEK SITE

W. R. GRACE AND COMPANY

MAY 1975

FIGURE III-2


System
Series
Group
Formation
Member
Thickness in feet
Quaternary (?)
Re-cent
Miocene or Later
TERTIARY
EOCENE
PALEOCENE
CRETACEOUS
UPPER CRETACEOUS
Mesaverde group
Wasatch
Fort Union
Lance
Lewis shale
Williams Fork
Iles
Mancos shale
Twentymile Sandstone
Trout Creek sandstone
Tow Creek sandstone
Frontier sandstone
Niobrara equivalent
White sand
Seymour coal
Kimberly coal
Lorello coal
Dry Creek coal
Upper coal group
Lennox coal
Wadge coal
Wolf Creek coal
Middle coal group
No. 3 coals
No. 2 coals
No. 1 coals
Lower coal groups
Gas shows at Tow Creek
Main oil zone at Tow Creek
1000+
1400±
1050-1500
1500-1900
1100-2000
1450-1550
4600
EXPLANATION
Coal
Limy shale
Shale
Gravel
Sandy shale
Sand and gravel
Sandstone
Basalt flows and plugs
Limestone
Vertical scale
3000 feet
2000
1000
0
300 feet to Dakota ss

GENERALIZED COLUMNAR SECTION OF EXPOSED ROCKS
IN PARTS OF ROUTT AND MOFFAT COUNTIES, COLORADO

formation. These sandstone units of the upper Mancos are silty, very fine grained, and thin-bedded in contrast to the massive, less silty sandstone units of the overlaying Mesaverde formation.

The Mesaverde group conformably overlies the Mancos shale. It consists of thick beds of light brown sandstone and some thick key beds of white sandstone interbedded with a gray shale, sandy shale, and coal beds. The thickness of the group varies but in the area of the study site was measured at 2,950 feet. In our study area the Mesaverde is divided into two important formations--the Iles formation below and the Williams Fork formation above.

The Iles formation consists of a thick sequence of ledge-forming sandstone beds interbedded with sandy shale, shale, and coal beds. At its top is a prominent ledge-forming white sandstone--the Trout Creek sandstone member.

The Williams Fork formation is similar to the Iles except that its sandstone units are distributed differently. Its sandstone beds consist chiefly of fairly well to well sorted fine grains of quartz. Most sandstone beds also contain many fine particles of clay. The bedding is regular and long, wedge-shaped units of crossbedded sandstone are common. It, too, consists of alternating beds of sandstone, sandy shale, carbonaceous shale, and coal.

A map showing the geologic formations in that portion of Axial Basin in which the Taylor Creek study site is located is presented on the map on the following page. It was adapted from E.T. Hancock, U.S.G.S. Bulletin 757.

In the Axial Basin the coal beds are uniformly distributed throughout the Williams Fork formation from its base to a level within about 200 feet of its top.

Figure III-3 includes a graphic section of coal beds in the Good Spring and Elkhorn Creek areas. (E.T. Hancock, U.S.G.S. Bulletin 757.)

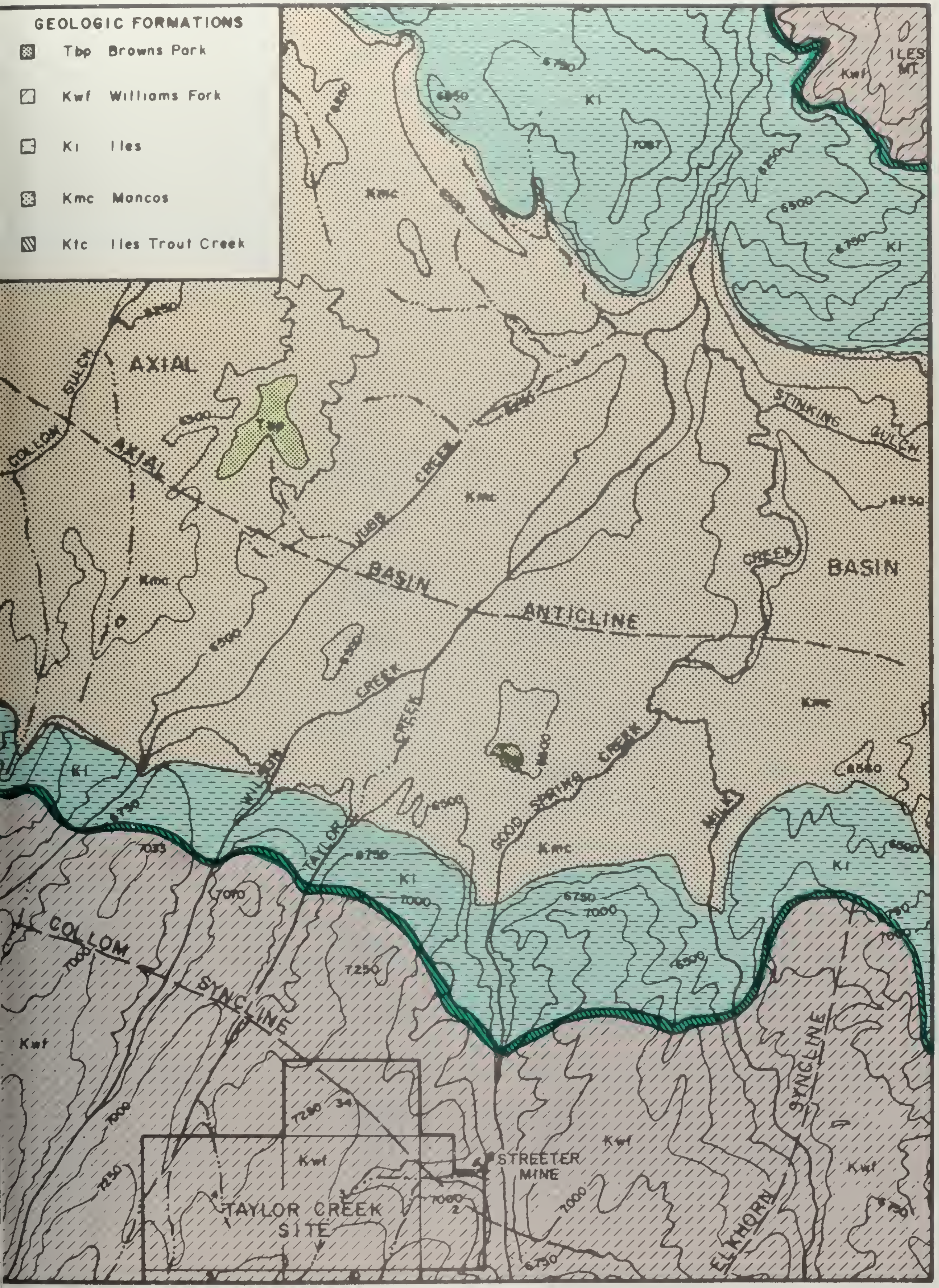
Site geology

Rocks in the study area are sedimentary in origin. The sequence, a part of the Williams Fork member of the Mesaverde formation, consists of sandstone, mudstone, shale, and coal with gradational contacts common. It has been estimated (Hancock 1925) that the stratigraphic thickness of the Williams Fork member is 1,600 feet thick in the vicinity of the study site.

Structure

The study site is dominated by the Collum syncline on the south limb of the Axial Basin anticline. The axis of the Collom syncline tends North

AXIAL BASIN


GEOLOGIC FORMATIONS
Tbp Browns Park
Kwf Williams Fork
Kı Iles
Kmc Mancos
Ktc Iles Trout Creek
ILES MT.
Kwf
Kı
Kmc
Tbp
AXIAL
COLLOM GULCH
AXIAL BASIN ANTICLINE
WILSON CREEK
STINKING GULCH
CREEK
BASIN
TAYLOR CREEK
GOOD SPRING CREEK
WILLOW
COLLOM SYNCLINE
ELKHORN SYNCLINE
STREETER MINE
TAYLOR CREEK SITE
34
2
6250
6500
6750
6850
7000
7033
7070
7087
7250

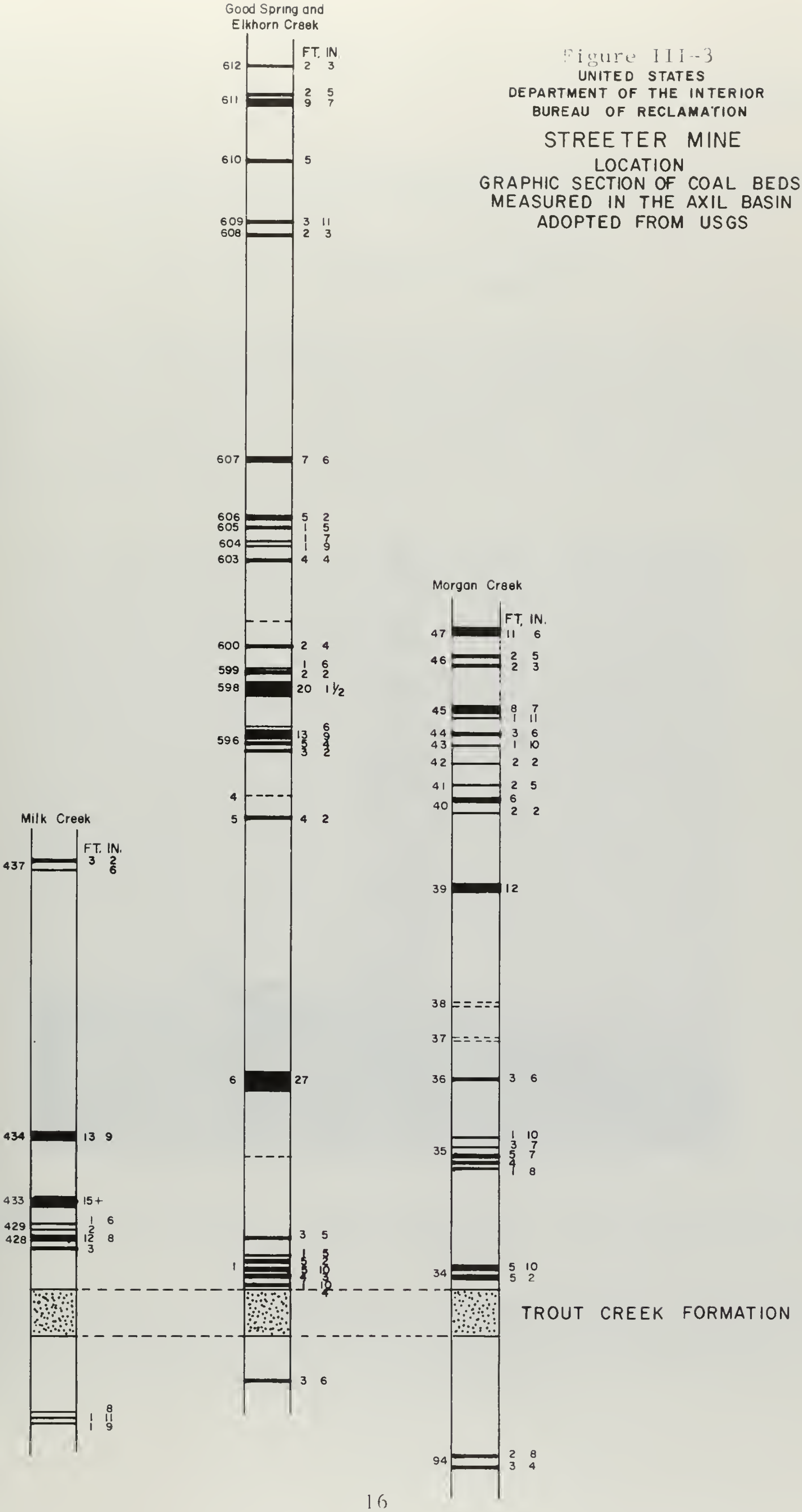
USBR

Figure III-3

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

STREETER MINE

LOCATION
GRAPHIC SECTION OF COAL BEDS
MEASURED IN THE AXIL BASIN
ADOPTED FROM USGS



80° to 85° west across the northern part of the study area. In general the geologic units have a northward dip throughout the area.

Technique, procedures, and standards used in geologic studies

Two holes, BR-101 and BR-102, were core drilled by the Bureau of Reclamation and completed as ground water observation wells. The holes were drilled NX in size with a skid-mounted Sprague and Henwood drill using clear water as drilling fluid. NX casing was used through the overburden soil and weathered rock near the surface. Upon completion of drilling, each core was logged by a Bureau of Reclamation geologist. The cores were photographed by W.R. Grace Company.

Sprague and Henwood drill at site BR-102.

Representative samples were sent to the Bureau of Reclamation's Soil Laboratory at Salt Lake City, Utah, for analysis. This information is included along with the geologic log of the Bureau of Reclamation core holes.

Upon completion of drilling, each core hole was cased and is being used as ground water observation wells in the hydrologic study by the United States Geological Survey. The geologic logs of drill holes BR-101 and BR-102 are shown in Figures III-4 and III-5.

7-1337 (9-69)
Bureau of Reclamation
GPO 854-401

GEOLOGIC LOG OF DRILL HOLE

FIGURE III-4
SHEET 1 OF 3

FEATURE Craig, Colorado Site PROJECT Coal Strip Mining BLM-BR STATE Colorado
HOLE NO BR-101 LOCATION Sec. 4, T. 3 N., R. 93 W.
COORDS. N. E. GROUND ELEV DIP (ANGLE FROM HORIZ.) -90
BEGUN 8-1-74 FINISHED 8-7-74 DEPTH OF OVERBURDEN 8 TOTAL DEPTH 217 BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 140.5 (8-8-74) LOGGED BY D. P. Weskamp

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION

Drill Rig: Skid-mounted Sprague and Henwood.

Drilling Fluid:
0-217 Water

Drilling Method:
0-15.2 4" Rock bit
15.2-217 NX core

Casing Record:

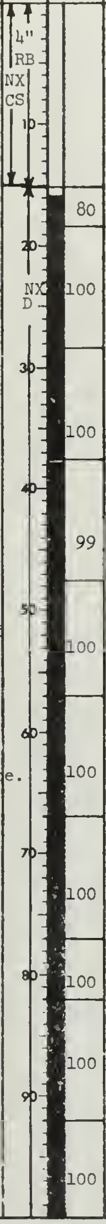
Casing Size	Casing Depth	Interval Drilled
-	-	0-15.2
NX	15	15.2-217

Drillwater Return:
0-139.5 Full return
139.5-217 No return

Pump Capacity:
18 gpm

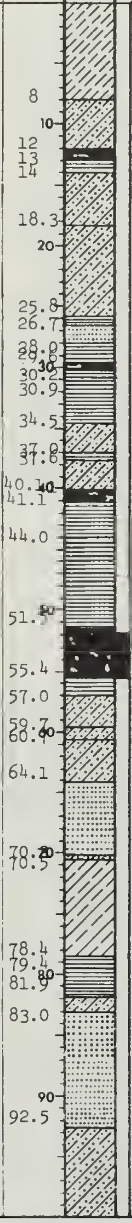
Drilling Conditions:
0-217
Smooth and easy

Hole Completion:
Installed 217 ft. of perforated plastic pipe (1½ in. dia.) for water level measurements. Grouted 3 ft. of 2 in. metal pipe at surface over plastic pipe.



NOTE:
Samples delivered to:
W. R. Grace & Company
1860 Lincoln Street
Lincoln Tower Building
Denver, Colorado 80203,
for testing.

Interval	Date
51.8 - 55.4	8-3-74
196.5 - 209.5	8-7-74



0-8 CLAY: (CL) Medium plasticity, moderate reaction to Hcl, dark to light brown, dry.

Holocene - Alluvium

8-217 SHALE, MUDSTONE, SANDSTONE, and COAL: predominantly light gray, well indurated, weakly cemented with lime, shale and mudstone with interbedded, fine to medium grained, weakly cemented light gray sandstone, dark gray carbonaceous mudstone and shale and black coal: many gradational contacts. Highty weathered and iron stained to 18.3 ft., core is fresh below 18.3 ft: Joints contain thin patchy calcite and disseminated pyrite and gypsum crystals.

Shale: Clayey to silty, fissile, eroded slightly during drilling, slakes upon drying, well indurated, reacts to Hcl, can be scratched with a penny. Core breaks with strong finger pressure, moderately jointed, some polished surfaces.

Mudstone: Clay, silt and fine sand with proportions of size fractions varying from place to place, well indurated, reacts to Hcl, generally can be scratched with a penny, breaks with firm hand pressure, moderately jointed.

Sandstone: Fine to medium grained, well sorted, generally silty, quick reaction to Hcl, breaks with light hammer blow, lightly jointed.

Coal: Relatively pure, shiny, very highly jointed.

Cretaceous - Williams Fork member of Mesaverde formation

8-12 Mudstone, intensely jointed, moderate reaction to Hcl, gray.
12-13 Coal, highly jointed, black
13-14 Carboniferous shale, fissile, intensely jointed, pieces range from fragments to 0.2 ft. long, light brown.
14-18.3 Mudstone, intensely jointed, pieces range from fragments to 0.2 ft. long, light brown.
18.3-25.8 Mudstone, light gray.

EXPLANATION

□ CORE LOSS
■ CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn, RB = Tri-Cone rock bit
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8" Nx = 3"

ATURE Craig, Colorado Site PROJECT Coal Strip Mining BLM-BR STATE Colorado SHEET 1 OF 3 HOLE NO. BR-101

7-1337 (9-69)
Bureau of Reclamation
GPO 884-401

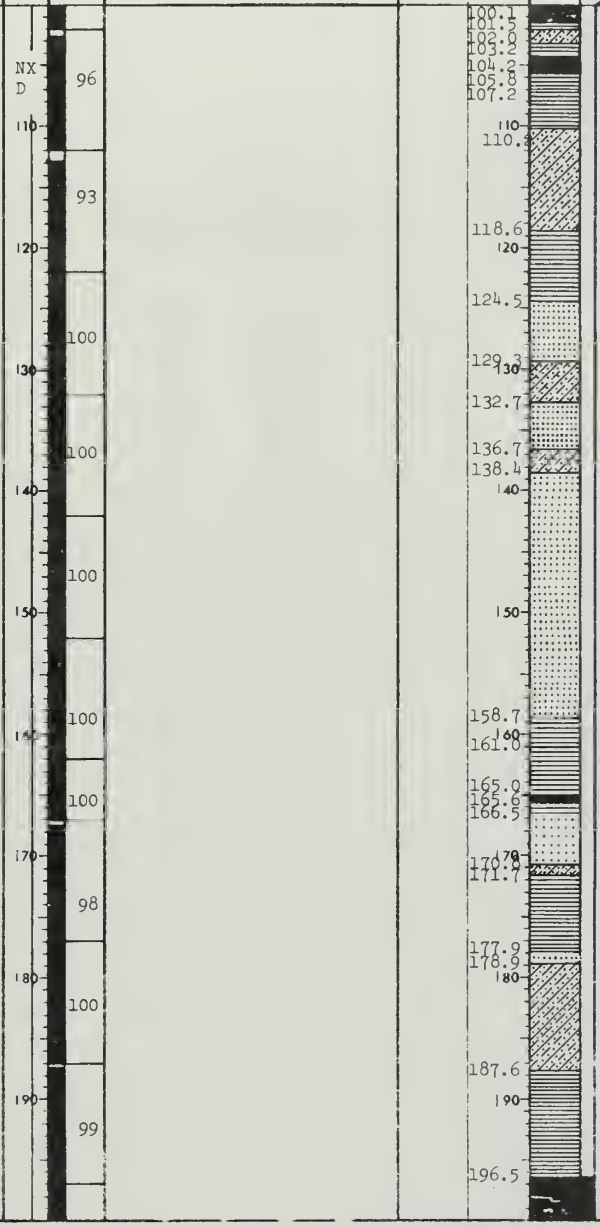
FIGURE III-4

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE Craig, Colorado Site PROJECT Coal Strip Mining, BLM-BR STATE Colorado
HOLE NO. BR-101 LOCATION Sec. 4, T. 3 N., R. 93 W. COORDS. N. E. GROUND ELEV. DIP (ANGLE FROM HORIZ.) -90
BEGUN 8-1-74 FINISHED 8-7-74 DEPTH OF OVERBURDEN 8 TOTAL DEPTH 217 BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 140.5 (8-8-74) LOGGED BY D. P. Weskamp

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION



25.8-26.7 Shale, dark gray
26.7-28.0 Sandstone, light gray
28.0-29.6 Carbonaceous shale, black
29.6-30.2 Coal, black
30.2-30.9 Carbonaceous shale, black
30.9-34.5 Shale, light gray
34.5-37.0 Mudstone, light gray
37.0-37.6 Shale, light gray
37.6-40.1 Mudstone, light gray
40.1-41.1 Coal, black
41.1-44.0 Carbonaceous shale, dark gray
44.0-51.5 Shale, dark gray
51.5-55.4 Coal, black
55.4-57.0 Shale, dark gray
57.0-59.7 Mudstone, light gray
59.7-60.7 Breccia (mudstone) light gray
60.7-64.1 Mudstone, light gray
64.1-70.2 Sandstone, light gray to 67.0, dark gray below
70.2-70.5 Breccia (Mudstone) dark gray
70.5-78.4 Mudstone, light gray
78.4-79.4 Carbonaceous shale, black
79.4-81.9 Shale, light gray
81.9-83.0 Mudstone, light gray
83.0-92.5 Sandstone, light gray
92.5-100.1 Mudstone, light gray
100.1-101.5 Coal, black
101.5-102.0 Carbonaceous shale, dark gray
102.0-103.2 Mudstone, light gray
103.2-104.2 Carbonaceous shale, dark gray
104.2-105.8 Coal, black
105.8-107.2 Carbonaceous shale, dark gray
107.2-110.2 Shale, light gray
110.2-118.6 Mudstone, light gray
118.6-124.5 Carbonaceous shale, dark gray
124.5-129.3 Sandstone, light gray
129.3-130.0 Carbonaceous mudstone, dark gray
130.0-132.7 Mudstone, light gray
132.7-136.7 Sandstone, light gray
136.7-138.4 Mudstone, light gray
138.4-158.7 Sandstone, light gray
158.7-161.0 Shale, light gray
161.0-165.0 Carbonaceous shale, dark gray
165.0-165.6 Coal, black
165.6-166.5 Carbonaceous shale, dark gray
166.5-170-8 Sandstone, light gray

EXPLANATION

☐ CORE LOSS
■ CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn, RB = Tri-cone rock bit
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1 5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Craig Colorado Site PROJECT Coal Strip Mining BLM-BR STATE Colorado SHEET 2 OF 3 HOLE NO. BR-101

7-1337 (9-69)
Bureau of Reclamation

GPO 584-401

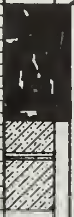
FIGURE III-4

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE Craig, Colorado Site PROJECT Coal Strip Mining BLM-BR STATE Colorado
HOLE NO. BR-101 LOCATION Sec. 4, T. 3 N., R. 93 W. COORDS. N. E. GROUND ELEV. DIP (ANGLE FROM HORIZ) -90
BEGUN 8-1-74 FINISHED 8-7-74 DEPTH OF OVERBURDEN 8 TOTAL DEPTH 217 BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 140.5 (8-8-74) LOGGED BY D. P. Weskamp

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)		ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	NX D	100						170.8-171.7 Mudstone, light gray 171.7-177.9 Shale, dark gray 177.9-178.9 Sandstone, light gray 178.9-187.6 Mudstone, light gray 187.6-196.5 Shale, dark gray 196.5-209.5 Coal, black
	210	100			209.5 210 212.2 212.7			209.5-212.2 Mudstone, light gray 212.2-212.7 Carboniferous Shale, black 212.7-217.0 Mudstone, light gray
			Bottom of Hole Drilled to required depth		217			
	220				220			



EXPLANATION

☐ CORE LOSS
■ CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn, RB = Tri-cone rock bit
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing

Approx. size of hole (X-series)	Ex = 1-1/2"	Ax = 1-7/8"	Bx = 2-3/8"	Nx = 3"
Approx. size of core (X-series)	Ex = 7/8"	Ax = 1-1/8"	Bx = 1-5/8"	Nx = 2-1/8"
Outside dia. of casing (X-series)	Ex = 1-13/16"	Ax = 2-1/4"	Bx = 2-7/8"	Nx = 3-1/2"
Inside dia. of casing (X-series)	Ex = 1-1/2"	Ax = 1-29/32"	Bx = 2-3/8"	Nx = 3"

FEATURE Craig, Colorado Site PROJECT Coal Strip Mining BLM-BR STATE Colorado SHEET 3 OF 3 HOLE NO. BR-101

FIGURE III-5

7-1337 (9-69)
Bureau of Reclamation
GPO 884-401

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Craig, Colorado Site PROJECT Coal Strip Mining BLM-BR STATE Colorado
HOLE NO. BR-102 LOCATION Sec. 3, T. 3 N., R.93 W. COORDS. N. E. GROUND ELEV. DIP (ANGLE FROM HORIZ.) -90
BEGUN 8-14-74 FINISHED 8-20-74 DEPTH OF OVERBURDEN 4 TOTAL DEPTH 198.5 BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY Dale Weskamp

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION

DRILL RIG: Skid-mounted Sprague & Henwood

DRILLING FLUID:
0-198.5 Water

DRILLING METHOD:
0-14 Rock bit
14-19815 NX core

CASING RECORD:

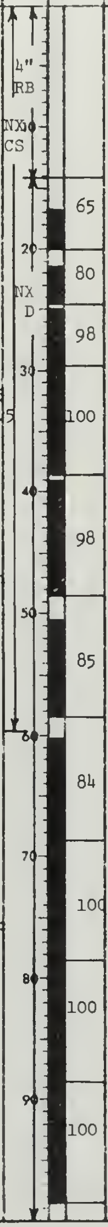
Casing size	Casing Depth	Interval Drilled
--	--	0-14
NX	14	14-20
NX	20	20-38.5
NX	21	38.5-58.5
NX	58.5	58.5-108.5
NX	59.5	108.5 - 198.5

DRILL WATER RETURN
1-14 Full return
14-20 No return
20-71.5 Full return
71.5-198.5 No return

PUMP CAPACITY
18 gpm

DRILLING CONDITIONS
0-198.5 Smooth and easy

HOLE COMPLETION
Installed 198 feet of perforated plastic pipe (1½ in. dia) for water level measurements. Grouted 3 ft. of 2 in. metal pipe at surface over plastic pipe.



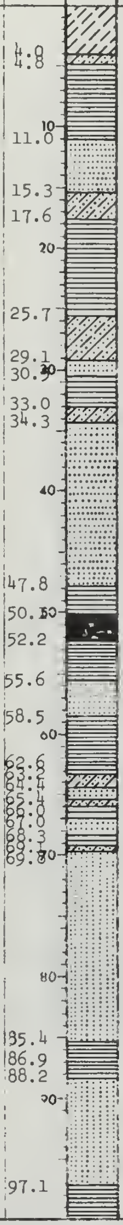
NOTE:

Samples delivered to:

W. R. Grace & Company
1860 Lincoln Street
Lincoln Tower Building
Denver, Colorado 80203

for testing.

Interval	Date
133.1-147.6	8-18-74
178.7-183.7	8-20-74



0-4 CLAY: (CL) Medium plasticity, moderate reaction to HCl, some organic matter, dark, brown, dry.
Holocene - Alluvium

4-198.5 SHALE, MUDSTONE, SANDSTONE, and COAL: predominantly light gray, well indurated, weakly cemented with lime, shale and mudstone with interbedded, fine to medium grained, weakly cemented light gray to light brown sandstone, dark gray carbonaceous shale, mudstone and sandstone, and black coal: many gradational contacts. Highly weathered and iron stained to 22 ft., core is fresh below 22 ft. Joints contain thin patchy colcite and disseminated pyrite crystals.

SHALE: Clayey to silty, fissile, eroded slightly during drilling, slakes upon drying, well indurated, reacts to HCl, can be scratched with a penny. Core breaks with strong finger pressure, moderately jointed, some polished surfaces.

MUDSTONE: Clay, silt and fine sand with proportions of size fractions varying from place to place, well indurated, reacts to Hcl, generally can be scratched with a penny, breaks with firm hand pressure, moderately jointed.

SANDSTONE: Fine to medium grained, well sorted, generally silty, quick reaction to HCl, breaks with light hammer blow, lightly jointed.

COAL: Relatively pure, shiny, very highly jointed.
Cretaceous-Williams Fork member of Mesaverde formation.

4-4.8 Mudstone, light brown, iron stained
4.8-11 Shale, light gray
11-15.3 Sandstone, light brown, iron stained
15.3-17.6 mudstone, light gray to 16.7 light brown below, iron stained
17.6-25.7 carboniferous shale, dark gray
25.7-29.1 carboniferous mudstone, dark gray

EXPLANATION

▯ CORE LOSS
■ CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn, RB = Tri-cone rock bit
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Craig Colorado Site PROJECT Coal Strip Mining BLM-BR STATE Colorado SHEET 1 OF 2 HOLE NO. BR-102

7-1337 (9-69)
Bureau of Reclamation

GFO 854-401

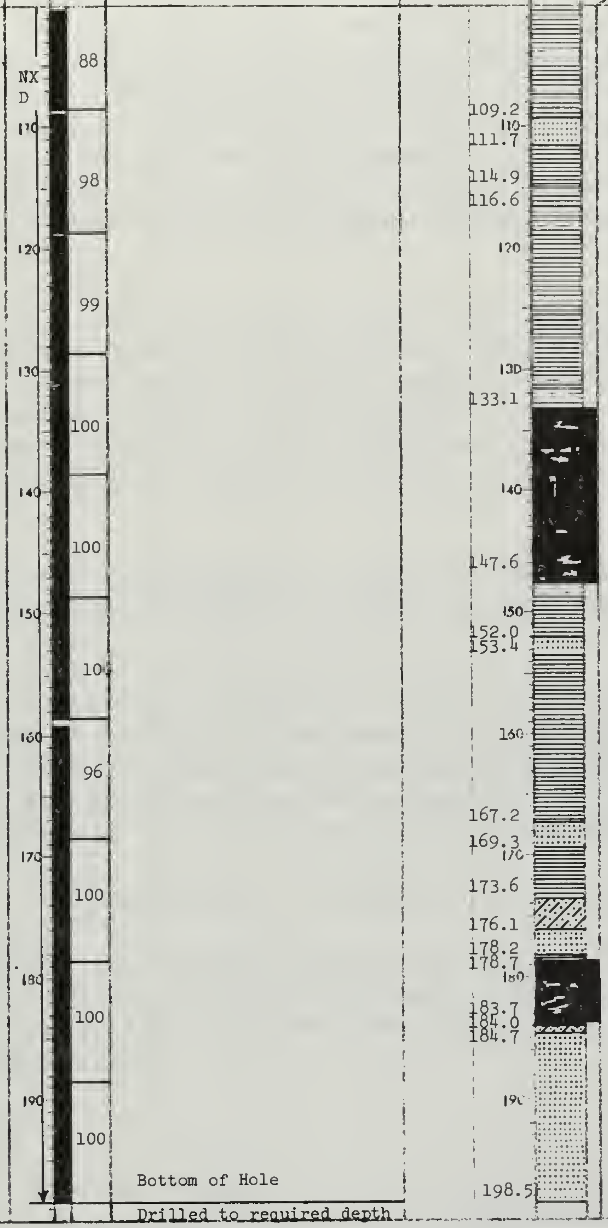
FIGURE III-5

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Craig Colorado Site PROJECT Coal Strip Mining, BLM-BR STATE Colorado
HOLE NO. BR-102 LOCATION Sec. 3, T. 3 N., R. 93 W. COORDS. N. E. GROUND ELEV. DIP (ANGLE FROM HORIZ.) -90
BEGUN 8-14-74 FINISHED 8-20-74 DEPTH OF OVERBURDEN 4 TOTAL DEPTH 198.5 BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED LOGGED BY Dale P. Weskamp

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION



29.1-30.5 carboniferous sandstone, dark gray
30.5-33.0 carboniferous shale, dark gray
33.0-34.3 Mudstone, light gray
34.3-47.8 sandstone, light brown
47.8-50.1 carboniferous shale, dark gray
50.1-52.2 coal, black
52.2-55.6 carboniferous shale, dark gray
55.6-58.5 sandstone, light gray
58.5-62.6 shale, gray
62.6-63.2 carboniferous shale, dark gray
63.2-64.4 mudstone, light gray
64.4-65.4 sandstone, light gray
65.4-66.0 mudstone, light gray
66.0-67.0 shale, light gray
67.0-68.3 sandstone, light gray
68.3-69.1 shale, gray
69.1-69.8 mudstone, light brown
69.8-85.4 sandstone, light brown
85.4-86.9 shale, light gray
86.9-88.2 carboniferous shale, dark gray
88.2-97.1 sandstone, light gray
97.1-109.2 shale, light gray
109.2-111.7 sandstone, light gray
111.7-114.9 shale, light gray
114.9-116.6 carbonaceous shale, dark gray
116.6-133.1 shale, light gray
133.1-147.6 coal, black
147.6-152.0 shale, light gray
152.0-153.4 Sandstone, light gray
153.4-167.2 Shale, light gray
167.2-169.3 Sandstone, light gray
169.3-173.6 Shale, light gray
173.6-176.1 Mudstone, light gray
176.1-178.2 Sandstone, light gray
178.2-178.7 Carbonaceous shale, dark gray
178.7-183.7 Coal, black
183.7-184.0 Carbonaceous shale, dark gray
184.0-184.7 Mudstone, light gray
184.7-198.5 Sandstone, light gray

Bottom of Hole

Drilled to required depth

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . . D = Diamond, H = Haystellite, S = Shot, C = Churn, RB = Tri-cone rock bit
Hole sealed . . . . P = Packer, Cm = Cemented, Cb = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Craig Colorado Site PROJECT Coal Strip Mining BLM-BR STATE Colorado SHEET 2 OF 2 HOLE NO. BR-102

Soils

General characteristics

The soils of the Axial Basin, including the Taylor Creek study site, have been formed by physical and chemical weathering of the original rock or parent material. Most soils are residual in nature. Parent material consists primarily of the alternating beds of sandstone, shale, and mudstone of the Williams Fork and Iles members of the Mesaverde formation. Climatic conditions are a dominant force in determining soil characteristics. Soils at the site have developed under a semiarid, dry to moist, continental climate.

Surface soils vary in texture, color, and depth depending upon their position. Surface soil textures vary from sandy loam to clay loam. Their dominant colors vary from light brown to brown but include the dark gray alluvial soils of the creek or stream bottoms. The organic matter content of these soils is low to moderate except in the creek bottoms or valleys that have higher organic matter which influences the darker colors of these soils.

Subsoils are predominantly clay but vary from clay loam to silty clay. They are usually lighter in color and contain moderate amounts of lime.

Typical soil profiles (BLM Form 7310-9) are presented for each major soil unit mapped at the site. Because of the limited soil survey work in the area only a generalized attempt was made to establish the taxonomic order and suborder names for the soils mapped. It was determined that most soil units would fall in the Mollisol order and Brolls suborder.

Description of natural soil bodies

Three natural soil bodies were recognized at the Taylor Creek site. These include: (1) those soils developed on the ridge tops of the rolling hill topography, (2) the steep side slopes, and (3) the narrow creek bottoms or valley lands.

Ridge Top Soils

The ridge tops are usually broad to narrow and slope to the north and northeast with a gradient of from 3 to 15 percent. These slopes break steeply to form an escarpment around the southern margin of Axial Basin just north of the study area boundary.

Ridge top soils are shallow to moderately deep (12 to 36 inches) and have areas of surface rock where the underlying geologic material outcrops near the surface. No gravels are present in these soils. They are calcareous throughout the profile with some zones of lime accumulations in

the subsoil. Lime mycelium is present and parent material usually consists of weathered sandstone and shale.

Inclusions or soil variations along the ridge tops include the alternating outcrops of shallow and rocky or stony soils encountered as you proceed downslope. These areas are small and scattered and were not delineated on the soil unit map.

The color of the surface soils varies but is predominantly dark grayish-brown to dark brown (10YR 4/2 to 10YR 3/3) based on the Munsell Soil Color Chart. Subsurface soils range from gray to light grayish-brown (10YR 5/1 to 10YR 5/2).

Surface soil textures vary between sandy loam and clay loam, while subsurface textures are mostly clay or silty clay. Most soils along the ridge tops are less than 48 inches in depth. Surface soil structure consists of weak, fine-to-medium platy or moderate, medium granular structure. The subsurface horizons have a moderate, medium blocky to a strong or very strong, coarse prismatic structure.

Typical soil profile of Taylor Creek site.

The consistency of these soils when dry is characterized by being soft to slightly hard at the surface and very hard to extremely hard in the subsoil. The surface soils are slightly sticky to sticky and plastic

to very plastic when wet. The permeability rates for soils along the ridge tops were classed as slow to moderately slow, 0.20 to 0.60 inch per hour. Moisture retention or water-holding capacity for these soils was rated as good, ranging between 4 and 6 inches per effective soil depth. Internal drainage of these soils appears to be slow to medium. Saturation of the soil profile occurs for short periods during the early spring. Position and topography account for a few wet or seeped areas that occur where large accumulations of winter snows melt slowly causing saturated soil and shallow water tables well into the summer months. This condition does not appear to adversely affect plant growth.

The ridge top soils are calcareous, nonsaline, and nonsodic. The cation exchange capacity for the surface and subsurface soil is such that plant nutrients are available and soil conditions are amenable to the establishment and propagation of adaptable vegetation. The cation exchange capacity, as expressed in me/100 grams, does not indicate a swelling type clay. The soil layers with a high cation exchange capacity were the dark, highly organic clays.

Most mottling in the soil profile was limited to iron stains, usually below the 12- to 18-inch depth. Depth to weathered material varies with location but on the ridges ranges between 18 to 48 inches.

Side Slope Soils

The side slope soils are steep, with gradients of 15 to 30 percent or greater. The soil mantle is very shallow (0 to 12 inches in depth). Surface textures are sandy loam to clay loam with finer textures in the subsoil. Soil color will vary some depending upon position and intensity of vegetative cover. North slopes with luxuriant vegetation have darker surface soil colors (10YR 3/2), very dark grayish-brown to dark brown (10YR 3/3). The sparsely vegetated or nearly barren side slope areas of shallow and rocky soils usually have lighter colored surface soils. They will range from a yellow (10YR 7/6) when dry to a yellowish-brown (10YR 5/6) when moist. Subsoil colors are similar to the ridge top natural soil bodies except where lime has accumulated and weathered material is close to the surface. Color of the zone of lime accumlation is usually light gray (10YR 7/2) when dry and pale brown (10YR 6/3) when moist.

Because of the steepness of slopes, these soils have little structural development. When developed under a vegetative cover of grass or low brush, they are weak, fine platy to weak, fine granular. Subsoil would be a weak, medium, angular blocky. Sparsely vegetated areas are structureless to a very weak, fine, angular blocky.

Soil consistency, expressed as soil cohesion or adhesion or resistance to deformation or rupture, is slightly hard to hard when dry, friable when moist, and slightly sticky to sticky when wet. These soils are also slightly plastic to plastic when wet.

There are no gravel deposits in these soils; they are, however, very rocky, with the steeper slopes almost cliff-like and composed of exposed shale and sandstone formations.

Deposits of scoria (red dog) or baked shale are exposed along Streeter Creek. These deposits have been used as roadbed material by the present lessee. Depth to weathered material for these soils is shallow to very shallow, less than 12 inches. Weathering of the geologic material extends to some depth, usually 2 to 3 feet.

The side slope soils are nonsaline and nonsodic. Permeability is slow to moderately slow and because of the steepness of some slopes these soils are subject to erosion. Their water-holding capacity is low due to their shallow effect depth.

Creek Bottoms or Valley Lands

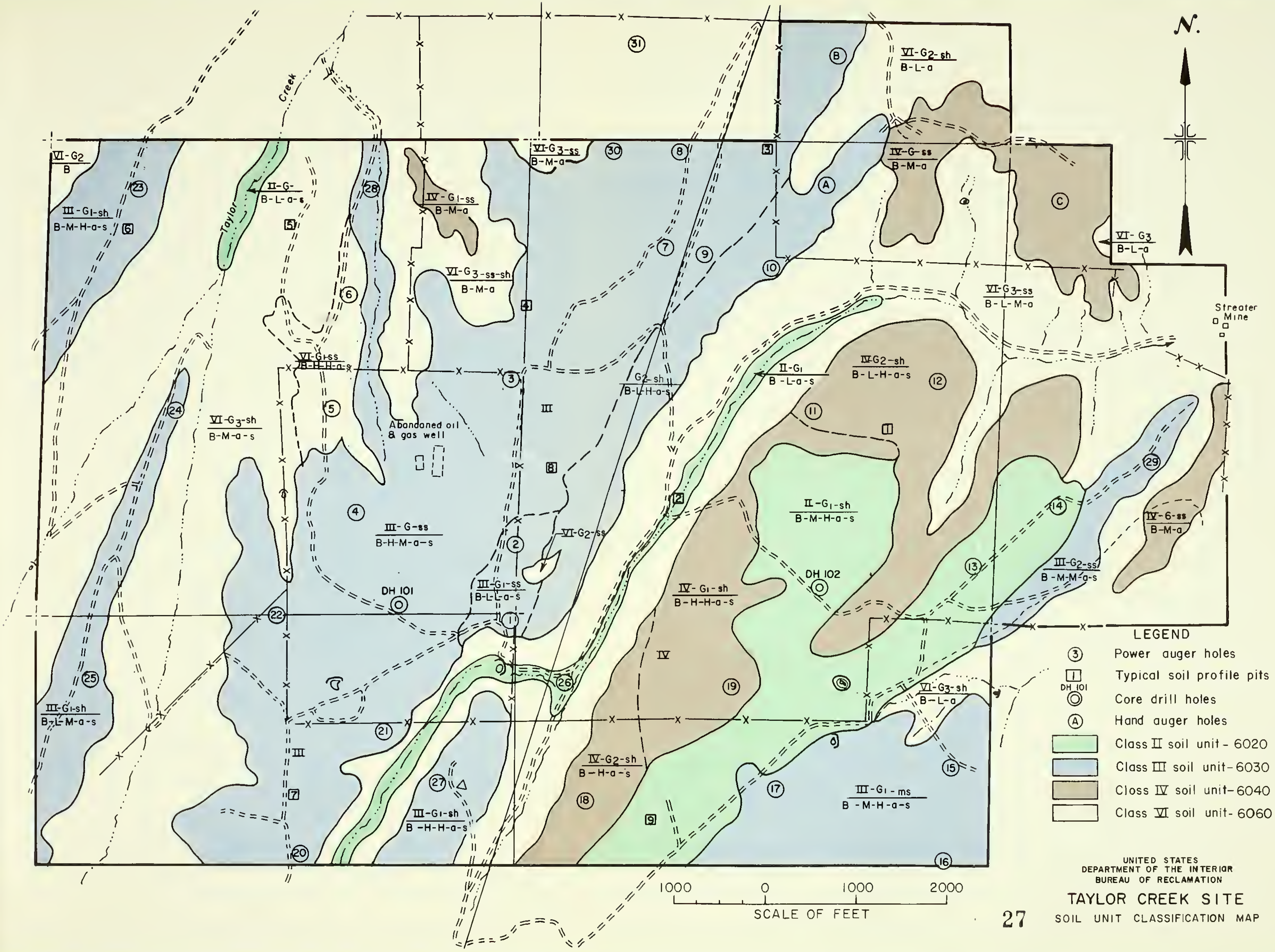
The creek bottoms and valley lands are narrow to very narrow at the site, usually less than 200 feet wide. Most soils are alluvial in origin, 48 to 60 inches or more in depth. They are moderate to moderately high in organic matter. Color is somewhat uniform throughout the profile. Surface soils are dark grayish-brown (10YR 4/2) when dry and very dark brown (10YR 2/2) when moist. Soil structure is only weakly developed due to their youthfulness. The surface soils have a weak, medium, granular structure and where developed under grass the horizon may be a very weak, fine, platy structure. Subsoils are structureless to very weakly developed. These soils are slightly calcareous, nonsaline, and nonsodic. Their cation exchange capacity is indicative of their textures and organic matter content.

The subsoils are stratified with small lenses of clay and gravel material that consists of water-worn sandstone and baked shale or scoria. There are also occasional large float rock or boulders on the surface and throughout the profile. A water table was noted at 17.6 feet on August 14, 1974 at typical profile site II.

Soil inventory

A detailed soil inventory was made at the Taylor Creek site. This inventory determined the location, extent, and quality of the surface soils and their potential for reclamation and revegetation. The surface soils were delineated into soil mapping units based on their distinguishing characteristics.

Four major soil units were indentified, rated, and delineated. These units are shown on the soil inventory map on the following page. A legend and typical soil unit symbol including the informative symbols and specifications used in this study are found on page 28. In order to maintain uniformity and correlation between districts and states, the following


N.
VI-G2 / B
III-G1-sh / B-M-H-a-s
II-G- / B-L-a-s
Taylor Creek
IV-G1-ss / B-M-a
VI-G3-ss-sh / B-M-a
VI-G3-ss / B-M-a
VI-G2-sh / B-L-a
IV-G-ss / B-M-a
VI-G3 / B-L-a
VI-G3-ss / B-L-M-a
Streater Mine
VI-G1-ss / B-H-H-a-s
VI-G3-sh / B-M-a-s
Abandoned oil & gas well
III-G-ss / B-H-M-a-s
G2-sh / B-L-H-a-s
II-G1 / B-L-a-s
IV-G2-sh / B-L-H-a-s
II-G1-sh / B-M-H-a-s
VI-G2-ss
III-G1-ss / B-L-L-a-s
DH 101
DH 102
IV-G1-sh / B-H-H-a-s
IV-6-ss / B-M-a
III-G2-ss / B-M-M-a-s
III-G1-sh / B-L-M-a-s
III-G1-sh / B-H-H-a-s
IV-G2-sh / B-H-a-s
VI-G3-sh / B-L-a
III-G1-ms / B-M-H-a-s
III
IV
A B C
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
1000 0 1000 2000
SCALE OF FEET

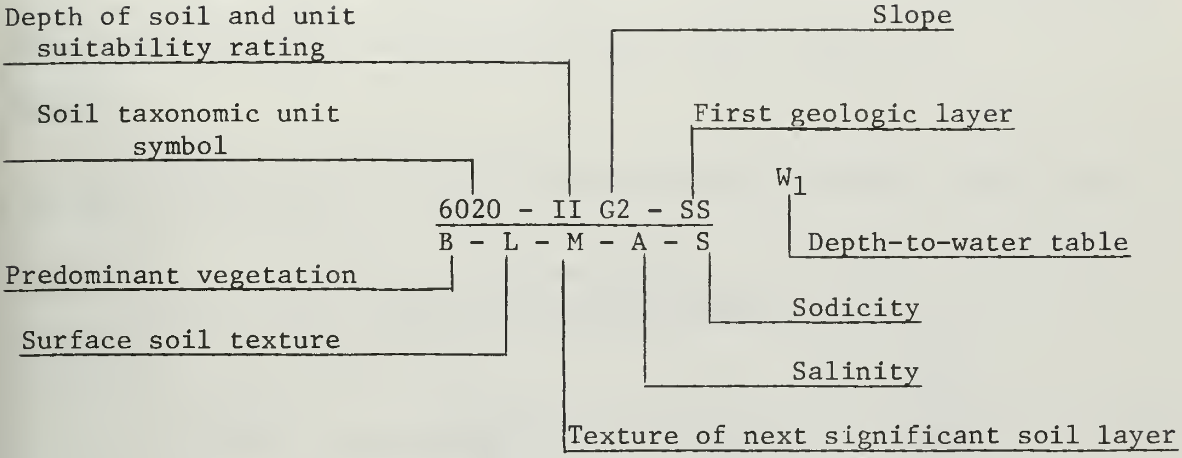
LEGEND

- ③ Power auger holes
- ▢1 Typical soil profile pits
- ◎ DH 101 Core drill holes
- Ⓐ Hand auger holes
- 🟩 Class II soil unit - 6020
- 🟦 Class III soil unit - 6030
- 🟫 Class IV soil unit - 6040
- ☐ Class VI soil unit - 6060

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

TAYLOR CREEK SITE
SOIL UNIT CLASSIFICATION MAP

SOIL MAPPING UNIT SYMBOL LEGEND


Depth of soil and unit suitability rating
Slope
Soil taxonomic unit symbol
First geologic layer
W_1
6020 - II G2 - SS
B - L - M - A - S
Depth-to-water table
Predominant vegetation
Sodicity
Surface soil texture
Salinity
Texture of next significant soil layer

Specifications

Colorado soil taxonomic unit symbol	
	6001 to 7000

	Depth of soil (inches)
I	60 or more
II	36-60
III	12-36
IV	Less than 12
VI	Less than 6

	Percent slope
G	0-5
G_1	5-15
G_2	15-35
G_3	Over 35

	Salinity (EC x 10^3)
a	0-4 millimhos
a_1	4-12 millimhos
a_2	12-18 millimhos

	Sodicity Exchangeable sodium
S	Less than 10 percent
S_1	Less than 15 percent
S_2	More than 15 percent

	Soil texture surface and next significant layers
L	Loamy sand, sandy loam, loam
M	Silt loam, clay loam silty clay loam
H	Sandy clay, silty clay, clay

	Vegetation or land use
B	Brush
T	Trees decideous
L	Dry land crops
G	Native grass
P	Pasture (irrigated)
C	Cultivated (irrigated)

	First geologic layer
SS	Sandstone
SH	Shale
Li	Limestone
MS	Mudstone or siltstone

	Depth of soil (inches)
W	36-60
W_1	18-36
W_2	Less than 18

sequence of numbers, 6001 to 7000, were assigned by the Bureau of Land Management to the State of Colorado for symbolization of soil taxonomic units. For the purpose of this study the major soil units were assigned the number 6020, 6030, 6040, and 6060 with variations, from these major units being numbered consecutively such as 6021, 6022, etc.

Results

The following table is an acreage summary of the soil units found at the Taylor Creek site.

Table III-1
Soil unit acreage summary

Soil units	State symbol	Acres	Percent of total area
II	6020	193.7	10
II	6021	40.0	
III	6030	826.0	36
IV	6040	307.7	14
VI	6060	912.6	40
Total		2,280.0	100

Description of Soil Units

Soil Unit I (6010) was not mapped at the Taylor Creek site.

Soil Unit II.--The soils for Unit II were assigned symbol number 6020. Most of the soils in this unit have developed from residual material. A typical soil profile describing the important soil characteristics is presented in Table III-2. Table III-3 presents laboratory data typical of Soil Unit II.

The soils for this mapping unit (6020) are moderately deep, slightly calcareous, with strong to moderate structural development. They are nonsaline, nonsodic, and surface textures vary from loam to clay loam. The subsoil textures are predominantly clay.

Topography for much of this land unit is rolling ridge tops with slopes varying between 3 to 5 percent. Aspect or exposure is usually to the north or northeast along the ridges sloping away from the high hills to the south. This soil unit represents approximately 10 percent of the total area.

Vegetation is predominantly sagebrush (*Artensia tridentata*) with an understory of native grass and forbs.

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TP-IX

VEGETATION–SOIL DESCRIPTION

1. State Colo.	2. District Craig	3. Planning Unit WF	4. Vegetation–Soil Unit Sage, serviceberry, grass, oak	5. Soil Map Symbol 6020	6. Surname McCoy, Brown, Bona, Masterson	7. Date 9 mo 12 yr 74
8. Area – –	9. County Moffat	10. Location Sec. 10, T. 3N, R. 93W	11. Photo No. – – – – – – – – – – –	12. Writeup No. – – – –	13. File No. – – – – – –	14. Parent Rock Shale & sandstone

15. Formation Name Mesaverde	16. Surface Conditions (*percent*) Stone – – Rock – –	17. Land Conditions Alkaline Saline Water table 18.2'	18. Landform Rolling Hills
19. Slope (*percent*) 5 ☐ Single [B] Complex	20. Aspect NE 21. Elevation – – – – – –	22. Present Erosion Slight Type Wind and water SSF – 17 Class 1	23. Hydrologic Group –

24. Precipitation (*in*) 18 1st , 2nd , 3rd , 4th	25. Temperature 60 Air – – Soil	26. Frost-free Days 128 – – > 28°	27. Drainage Class Moderate well drained	28. Infiltration Moderate	29. Percolation Slow	30. ERD 48 in	31. AWC High. – in

32. HORIZON	33. THICKNESS (IN)	34. COLOR DRY MOIST		35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (*pH*) 1:5	42. BOUNDARY
		MATRIX	MOTTLING								
A	0-2.5	10yr 4/2 D 10yr 3/2 M	-	Silty Loam	f-f-pl	So - D Fr - M	-	3f-vf ran	-	7.3	Clear & Smooth
A_1	2.5-10	10yr 4/2 D 10yr 3/2 M	-	Silty clay Loam	3-f-sbk	h - D Fi - M	-	1-f ran	-	7.2	Clear & smooth
B_1	10-22	10yr 4/2 D 10yr 4/3 M	-	Clay	2-M-Pr	Vh - D Fi - M	4K-Pf	1-M ver	1	8.5	Top-abrupt and wavy. Bottom clear & smooth
B_2											
B_{22t}	22-40	5yr 5/3 D 5yr 5/3 M	2.5y 8/0	Clay	1-M-Pr to 3-M-sbk	Vh - D Fi - M	-	1-M ver	-	9.2	Clear & wavy
B_{32}	40-48	5y 5/3 D 5y 4/3 M	2.5y 8/0	Silty Clay	2-M-sbk	Vh - D Fi - M	-	1-M ver	2.0	9.1	Clear & wavy
R	48-60			Shale							

Table III-2

TP-IX

43. Allotment
44. Pasture
45. Acres ______
46. Surname ________________________
47. Date __ mon __ yr
48. Transect No. ________

TRANSECT HITS

W.

VEGETATION			OVERSTORY *		51. COVER (percent)	UNDERSTORY			55. TOTAL HITS	56. COMPOSITION (percent)
			49 BASAL	50 CANOPY		52 BASAL	53 CANOPY	54 TOTAL		
GRASSES	W. Blue									
	grass				20					
FORBS	Snowberry				10					
WOODY SPECIES	Sage									
	Serviceberry									
	Oak				40					
						70					
SUBTOTAL										100
LITTER†	BASAL	P								
		NP								
	CANOPY	P								
		NP								
ROCK	SMALL	1/8" to 2"								
	LARGE	2"+								
Bare ground										
TOTAL					100					

57. VEGETATION	58. LITTER	ROCK 59 SMALL	ROCK 60. LARGE	61. BARE GROUND	62. TOTAL COVER
70	20			10	100

* *Record Litter, Rock, and Bare ground in Column 49 when they are not under a canopy*
† *P, persistent; NP, nonpersistent; last less than 2 years*

TABLE III-3

ANALYSIS OF SOILS

Project USBR-BLM Coal Overburden

Collected by By J. McCoy - C.D. Brown **Date** **Received** 9/13/74

Analyzed by Hyde, Hatfield, Sory, Furneau **Date** 10/29/74

Location and Class

Vegetation

SAMPLE						
Lab No.	111	112	113	114	115	
Field No.	TP-9	TP-9	TP-9	TP-9	TP-9	
Depth, inches	0-2½	2½-10	10-22	22-40	40-48	
Field texture						
SOIL						
Saturation percentage	52.9	48.6	71.7	70.5	60.9	
pH paste	7.0	6.8	7.3	7.9	8.1	
pH, 1:5 dilution	7.3	7.2	8.5	9.2	9.1	
Insoluble carbonates	low	low	med	hi	hi	
Gypsum me/100 gm.	.16		.67	.58	.50	
Organic matter, percent						
SATURATION EXTRACT						
Conductivity EC x 10³ @ 25°C	.929	.975	.420	.354	.352	
pH	8.0	8.2	8.6	8.2	8.2	
Dissolved solids p.p.m.	804	880	354	192	192	
Boron p.p.m.						
Carbonate me./l			.42			
Bicarbonate me./l	6.30	7.91	3.58	3.12	2.90	
Chloride me./l	.44	.39	.07	.15	.02	
Sulfate me./l	3.58	1.69	.74	.41	.72	
Calcium me./l	6.04	6.48	2.40	2.02	1.40	
Magnesium me./l	2.32	3.12	2.10	1.38	1.72	
Sodium me./l	.48	.28	.24	.36	.68	
Potassium me./l	1.42	.67	.11	.03	.03	
S.A.R.	.2	.1	.2	.3	.5	
EXCHANGE RELATIONS						
Total sodium me./100 gm.	.30	.28	.40	.48	.50	
Soluble sodium me./100 gm.	.03	.01	.17	.02	.04	
Exchangeable sodium me./100 gm.	.27	.27	.23	.46	.46	
Cation exchange capacity me./100 gm.	26.81	26.75	44.75	35.00	27.94	
Exchangeable sodium percent	1.0	1.0	.5	1.3	1.7	
PARTICLE SIZE ANALYSIS						
Percent > 2 m.m.						
Percent sand .05 - 2 m.m.	20.8	17.8	14.4	6.4	8.4	
Percent silt .002 - .05 m.m.	54.0	46.8	34.2	36.6	48.2	
Percent clay < .002 m.m.	25.2	35.4	51.4	57.0	43.3	
Texture	Silt loam	Silty clay loam	clay	clay	Silty clay	

Variations from the typical profile consist principally of the deep valley filling material in the steep narrow stream bottoms of the area. These soils have greater depth (60 or more inches). They consist of dark alluvium with a dominant loam to clay loam texture. They are somewhat stratified with small layers or lenses of course material consisting of water-worn sandstone rock fragments or gravels. Occasional float rock occurs both on the surface and throughout the profile.

A typical profile indicates a soil depth of 18 feet and is shown in Tables III-4 and 5. A moving water table was noted at 17.6 feet. This soil unit has been designated as Unit No. 6021 and is less than 1 percent of the total area.

Soil Unit III.--The soils for Unit III were assigned symbol No. 6030. They are shallow (12 to 36 inches), slightly calcareous, and have strong structural development. The slopes are from 5 to 15 percent, confined mostly to ridge tops and north or northwestern exposed side slopes. The surface texture is usually loam, and the subsoils textures will vary from clay loam to clay. They are nonsaline, nonsodic, and low in organic matter.

The soils of this unit that have developed under scrub oak (Quercus gambelii) with northwestern exposures have surface textures that vary from loam to sandy loam. These surface soils appear to be aeolian deposits accumulating in brush areas. Typical profile and laboratory data are presented in Tables III-6 and III-7. The soils of this unit contain approximately 36 percent of the total area.

The vegetative cover on the north and northwestern exposed slopes is predominantly as follows: (1) scrub oak (Quercus gambelii), (2) scattered clumps of Utah serviceberry (Amelanchier utahensis), (3) snowberry (Symphoricarpos oreophilus), and (4) stands of quaking aspen trees (Populus tremuloides) at the head of draws in small moist depressions. Usually there is a good understory of native grasses in these heavily wooded areas. The vegetation along the tops of ridges on the northeast exposed slopes is predominantly big sagebrush, (Artemisia tridentata), also a few sparsely scattered clumps of Utah serviceberry, (Amelanchier utahensis), with a fairly good understory of native grasses.

Soil Unit IV.--The soils for this unit were assigned symbol No. 6040 and are very shallow, less than 12" in depth. In most cases they are slightly calcareous. The structure is weak to subangular blocky. The surface textures vary from loam to clay loam, and the subsurface textures are predominantly clay. The slopes are from 15 to 30 percent and have a considerable amount of rock exposed on the surface. These surface rock fragments are weathered sandstone and mudstone of various sizes. This unit represents approximately 14 percent of the area.

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TP-II

VEGETATION–SOIL DESCRIPTION

1. State Colo
2. District Craig
3. Planning Unit WF
4. Vegetation–Soil Unit Sage, Basin rye, / Snowberry
5. Soil Map Symbol 6020
6. Surname McCoy, Brown, Bona, Masterson
7. Date 8 mo 29 yr 74
8. Area – –
9. County Moffat
10. Location Sec. 3, T. 3N, R. 93W
11. Photo No. – – – – – – – – – – –
12. Writeup No. – – – –
13. File No. – – – – – –
14. Parent Rock Shale & sandstone
15. Formation Name Mesaverde
16. Surface Conditions (*percent*) Stone – – Rock – –
17. Land Conditions Alkaline Saline Water table
18. Landform Rolling Hills
19. Slope (*percent*) 3 ☐ Single ☒ Complex
20. Aspect NE
21. Elevation – – – – –
22. Present Erosion Slight Type Wind & water SSF 36 Class 2
23. Hydrologic Group –
24. Precipitation (*in*) 18 1st, 2nd, 3rd, 4th
25. Temperature 60 Air – – Soil
26. Frost-free Days 128 –> 28°
27. Drainage Class Moderate well drained
28. Infiltration Moderate
29. Percolation Moderate
30. ERD 60 in
31. AWC Medium – –.– in

32. HORIZON	33. THICKNESS (IN)	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1:5	42. BOUNDARY
A_1	0-12	10yr 4/2 D 10yr 2/2 M	-	Loam	2 M Cr	So-D Fr - M		3f Ran 1M Ver	5	8.0	Gradual smooth
A_2	12-60	10yr 4/3 D 10yr 2/2 M	-	Clay loam	1 M Cr	So-D Fr-M		3f Ran 1M Ver	8.1	-	-

Table III-4

TP-II

43. Allotment	44. Pasture	45. Acres ______
46. Surname ______________________	47. Date — — mon — — yr	48. Transect No. ________

TRANSECT HITS

VEGETATION		OVERSTORY * 49. BASAL	OVERSTORY * 50. CANOPY	51. COVER (percent)	UNDERSTORY 52. BASAL	UNDERSTORY 53 CANOPY	UNDERSTORY 54 TOTAL	55. TOTAL HITS	56. COMPOSITION (percent)
GRASSES	Basin								
	Rye								
	Poa								
	Blue			5					
FORBS									
	Gum weed								
	Bull thistle			5					
	Snowberry			10					
WOODY SPECIES									
	Serviceberry								
	Choke Cherry								
	Sage			30					
SUBTOTAL				50					100
LITTER† BASAL	P								
	NP								
LITTER† CANOPY	P								
	NP								
ROCK SMALL	1/8" to 2"								
ROCK LARGE	2"+								
Bare ground									
TOTAL				100					

57. VEGETATION	58. LITTER	ROCK 59. SMALL	ROCK 60 LARGE	61. BARE GROUND	62. TOTAL COVER
50	20	10		20	100

GPO 832-491

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* *Record Litter, Rock, and Bare ground in Column 49 when they are not under a canopy*

† *P, persistent; NP, nonpersistent; last less than 2 years*

TABLE III-5
ANALYSIS OF SOILS

Project BLM-USBR Coal Overburden

Collected by J. McCoy - C.D. Brown **Date** **Received** 9/13/74

Analyzed by Hyde, Hatfield, Sory, Furneaux **Date** 10/23/74

Location and Class

Vegetation

SAMPLE						
Lab No.	87					
Field No.	TP-2					
Depth, inches	0-12					
Field texture						
SOIL						
Saturation percentage	39.4					
pH paste	6.9					
pH, 1:5 dilution	8.0					
Insoluble carbonates	none					
Gypsum me/100 gm.	.19					
Organic matter, percent						
SATURATION EXTRACT						
Conductivity EC x 10^3 @ 25°C	.341					
pH	8.4					
Dissolved solids p.p.m.	108					
Boron p.p.m.						
Carbonate me./l						
Bicarbonate me./l	3.24					
Chloride me./l	.29					
Sulfate me./l	none					
Calcium me./l	1.83					
Magnesium me./l	.75					
Sodium me./l	.18					
Potassium me./l	.91					
S.A.R.	.2					
EXCHANGE RELATIONS						
Total sodium me./100 gm.	.25					
Soluble sodium me./100 gm.	.01					
Exchangeable sodium me./100 gm.	.24					
Cation exchange capacity me./100 gm.	28.75					
Exchangeable sodium percent	.8					
PARTICLE SIZE ANALYSIS						
Percent > 2 m.m.						
Percent sand .05 - 2 m.m.	31.6					
Percent silt .002 - .05 m.m.	46.6					
Percent clay < .002 m.m.	21.8					
Texture	Loam					

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BUREAU OF LAND MANAGEMENT

TP-VIII

VEGETATION–SOIL DESCRIPTION

1. State Colo	2. District Craig	3. Planning Unit WF	4. Vegetation–Soil Unit Serviceberry, sage, grass	5. Soil Map Symbol 6030	6. Surname McCoy, Brown, Bona, Masterson	7. Date 9 mo 12 yr 74
8. Area – –	9. County Moffat	10. Location Sec. 3, T. 3N, R. 93W	11. Photo No. – – – – – – – – – – –	12. Writeup No. – – – –	13. File No. – – – – – – –	14. Parent Rock Shale & sandstone

15. Formation Name Mesaverde	16. Surface Conditions (*percent*) Stone – – Rock – –	17. Land Conditions Alkaline Saline Water table	18. Landform Rolling Hills
19. Slope (*percent*) 3 ☐ Single [B] Complex	20. Aspect E / 21. Elevation – – – – –	22. Present Erosion Slight Type Wind and water SSF 17 Class 1	23. Hydrologic Group –

24. Precipitation (*in*) 18 1st , 2nd , 3rd , 4th	25. Temperature 60 Air – – Soil	26. Frost-free Days 128 –> 28°	27. Drainage Class Moderate well drained	28. Infiltration Moderate	29. Percolation Slow	30. ERD 37 in	31. AWC High – . – in

32. HORIZON	33. THICKNESS (IN)	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (*pH*) 1:5	42. BOUNDARY
Ao	0.5-0	5yr 3/3 D 5yr 3/2 M	-	Organic	-	So - D fr - M	-	3f-vf ran	-	-	Clear & Smooth
A_1	0-5	5yr 4/1 D 5yr 3/1 M	-	Loam	1-2-f-pl	So - D fr - M	-	3f-vf ran	-	7.4	Clear & smooth
B_{21t}	5-16	10yr 4/2 D 10yr 4/2 M	10yr 6/8	Clay	3M - Pr	Vh - D fi - M	4K-Pf	1-f-M ver	-	8.4	Clear & wavy
B_{22t}	16-22	10yr 4/2 D 10yr 4/2 M	10yr 8/1	Clay	3M - abk	Vh - D fi - M	4K-Pf	1-f-M ver	-	8.5	Clear & wavy
C	22-37	7.5yr 2/0 D 7.5yr 2/0 M	7.5yr 8/0	Clay	Mf - gr	Sh - D fl - M	-	1-M ver	-	8.3	Clear & smooth
R	37-60	7.5yr 5/0 D 7.5yr 4/0 M	-	Shale	Mf - Pl	Sh - D fr - M	-	1-M ver	-	-	Abrupt & wavy

Note
Large cracks 90 from 0-30" about ½" wide

Table III-6

TP-VIII

43. Allotment

44. Pasture

45. Acres ______

46. Surname ______________________

47. Date __ mon __ yr

48. Transect No. ________

TRANSECT HITS

			OVERSTORY *		51. COVER (percent)	UNDERSTORY			55. TOTAL HITS	56. COMPOSITION (percent)
VEGETATION			49. BASAL	50. CANOPY		52. BASAL	53. CANOPY	54. TOTAL		
GRASSES		Rye								
		W. Blue			10					
FORBS		Snowberry			10					
WOODY SPECIES		Sage			20					
		Serviceberry			10					
		Oak			20					
SUBTOTAL					70					100
LITTER†	BASAL	P								
		NP								
	CANOPY	P								
		NP								
ROCK	SMALL	1/8" to 2"								
	LARGE	2"+								
Bare ground										
TOTAL					100					

57. VEGETATION	58. LITTER	ROCK		61. BARE GROUND	62. TOTAL COVER
		59 SMALL	60 LARGE		
70	10			20	100

* *Record Litter, Rock, and Bare ground in Column 49 when they are not under a canopy*
† *P, persistent; NP, nonpersistent; last less than 2 years*

GPO 832-491

TABLE III-7

ANALYSIS OF SOILS

Project USBR-BLM Coal Overburden

Collected by J.MCCoy-C. D. Brown **Date** **Received** 9/13/74

Analyzed by Hyde, Hatfield, Sory, Furneaux **Date** 10/29/74

Location and Class Sec. 3

Vegetation

SAMPLE						
Lab No.	107	108	109	110		
Field No.	TP-8	TP-8	TP-8	TP-8		
Depth, inches	0-5	5-16	16-22	22-37		
Field texture						
SOIL						
Saturation percentage	38.9	72.3	77.8	61.1		
pH paste	6.8	7.2	8.1	8.1		
pH, 1:5 dilution	7.4	8.4	8.5	8.3		
Insoluble carbonates	low	low	med	low		
Gypsum me / 100 gm.	.66	.52		4.86		
Organic matter, percent						
SATURATION EXTRACT						
Conductivity EC x 10^3 @ 25°C	.963	.883	2.83	9.51		
pH	8.2	8.7	8.6	8.3		
Dissolved solids p.p.m.	732	540	2370	5850		
Boron p.p.m.						
Carbonate me./l		1.83	.43			
Bicarbonate me./l	9.41	6.42	3.60	4.20		
Chloride me./l	.78	.29	1.02	7.84		
Sulfate me./l	1.48	1.55	30.49	143.6		
Calcium me./l	4.41	1.83	5.40	24.00		
Magnesium me./l	4.89	4.26	13.00	74.50		
Sodium me./l	1.38	4.11	18.60	56.00		
Potassium me./l	.99	.20	.11	.30		
S.A.R.	.6	2.3	6.1	8.8		
EXCHANGE RELATIONS						
Total sodium me./100 gm.	.40	1.13	3.90	6.88		
Soluble sodium me./100 gm.	.05	.30	1.45	3.76		
Exchangeable sodium me./100 gm.	.35	.83	2.45	3.12		
Cation exchange capacity me./100 gm.	21.38	35.13	37.75	51.75		
Exchangeable sodium percent	1.6	2.4	6.5	6.0		
PARTICLE SIZE ANALYSIS						
Percent > 2 m.m.						
Percent sand .05 - 2 m.m.	38.6	21.4	11.8	13.4		
Percent silt .002 - .05 m.m.	36.0	24.4	28.8	39.6		
Percent clay < .002 m.m.	25.4	54.2	59.4	47.0		
Texture	loam	clay	clay	clay		

Shallow soil over weathered shale.

The vegetative cover on this unit is predominantly big sagebrush, (Artemisia tridentata) and, because of the shallow soil conditions, shows signs of poor growth. There are sparsely scattered clumps of Utah serviceberry (Amelanchier utahensis), Utah juniper (Juniperus esteosperria), with some native grasses as an understory. Typical profile and laboratory data are presented in Tables III-8 and 9.

Soil Unit V (6050) was not mapped at the Taylor Creek site.

Soil Unit VI.--The soils for Unit VI were assigned symbol No. 6060 and are found on the steeper side slopes. Soils on the east and south exposures have been mostly eroded away, exposing the rock ledges and cliffs of sandstone, mudstone, or shales that have steep gradients, 60 percent or more. The surface texture of these very shallow soils, usually less than 12 inches, will vary from sandy loam to clay loam. The soils are nonsaline and calcareous.

The vegetative types found on this unit are similar to other soil units. The cover varies from sparsely scattered Utah juniper to thick stands of scrub oak. Understory growth consists of native grasses and forbs. A typical profile sheet and laboratory data are presented in Tables III-10 and 11. This soil unit accounts for nearly 40 percent of the total area studied.

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TP-I

VEGETATION–SOIL DESCRIPTION

1. State Colo.
2. District Craig
3. Planning Unit WF
4. Vegetation–Soil Unit Oak, sage, serviceberry
5. Soil Map Symbol 6040
6. Surname Brown, Bona, Masterson, McCoy
7. Date 8 mo 29 yr 74
8. Area TC
9. County Moffat
10. Location Sec. 3, T. 3N, R. 93W
11. Photo No. - - - - - - - - - -
12. Writeup No. - - - -
13. File No. - - - - - -
14. Parent Rock Shale & sandstone
15. Formation Name Mesaverde
16. Surface Conditions (*percent*) Stone - - Rock - -
17. Land Conditions Alkaline Saline Water table
18. Landform Rolling Hills
19. Slope (*percent*) 3 ☐ Single B Complex
20. Aspect N
21. Elevation - - - - -
22. Present Erosion Slight Type Wind and water SSF 18 Class 1
23. Hydrologic Group -
24. Precipitation (*in*) 18 1st, 2nd, 3rd, 4th
25. Temperature 60 Air - - Soil
26. Frost-free Days 128 > 28°
27. Drainage Class Moderate well drained
28. Infiltration Moderate
29. Percolation Moderate
30. ERD 21 in
31. AWC Medium -.- in

32. HORIZON	33. THICKNESS (IN)	34. COLOR DRY MOIST MATRIX	34. COLOR MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1:5	42. BOUNDARY
Ao	0.5-0	10yr 3/2 D 10yr 2/2 M	-	Organic Matter	-	SO-D VFR-M		3f-vf Ran.		-	Clear & smooth
A1	0-3.5	10yr 3/2 D 10yr 3/1 M	-	Loam	2 M Cr	So-D fr-M		3f-M Ran.		7.0	Clear & wavy
A2	3.5-21	10yr 3/3 D 10yr 3/1 M	10yr 6/8	Loam	3 M sbk	h - D fi - M		2f-M Ver.		7.2	Clear & wavy
C	21-46	10yr 3/2 D 10yr 5/2 M	10yr 5/4	Clay loam (shale)	3 VC Pr	vh - D fi - M	4k	IM-Ver		7.6	Abrupt&wavy
R	46-60	-	-	Shale	-	-	-	-	-	-	-

NOTE: C horizon is weathered shale.

Table III-8

TP-I

43. Allotment	44. Pasture	45. Acres ______
46. Surname ____________________	47. Date — — mon — — yr	48. Transect No. ________

TRANSECT HITS

VEGETATION			OVERSTORY * 49 BASAL	OVERSTORY * 50. CANOPY	51. COVER (percent)	UNDERSTORY 52. BASAL	UNDERSTORY 53 CANOPY	UNDERSTORY 54. TOTAL	55. TOTAL HITS	56. COMPOSITION (percent)
GRASSES	Poa									
	Blue									
	grasses				15					
FORBS										
	Holly									
	yarrow									
	vetch				5					
WOODY SPECIES										
	Sage				35					
	Snow-									
	berry				10					
SUBTOTAL					65					100
LITTER†	BASAL	P								
		NP								
	CANOPY	P								
		NP								
ROCK	SMALL	1/8" to 2"								
	LARGE	2"+								
Bare ground										
TOTAL					100					

57. VEGETATION	58. LITTER	ROCK 59 SMALL	ROCK 60. LARGE	61. BARE GROUND	62. TOTAL COVER
65	20	5		10	100

GPO 832-491

* *Record Litter, Rock, and Bare ground in Column 49 when they are not under a canopy*

† *P, persistent; NP, nonpersistent; last less than 2 years*

TABLE III-9

ANALYSIS OF SOILS

Project USBR - BLM Coal Overburden

Collected by J.McCoy - C.D. Brown Date Received 9/13/74

Analyzed by Hyde,Hatfield,Sory,Furneaux Date 10/22/74

Location and Class

Vegetation

SAMPLE						
Lab No.	84	85	86			
Field No.	TP-1	TP-1	TP-1			
Depth, inches	0-3.5	3.5-21	21-46			
Field texture						
SOIL						
Saturation percentage	45.0	41.5	44.0			
pH paste	6.6	6.6	6.5			
pH, 1:5 dilution	7.0	7.2	7.6			
Insoluble carbonates	none	none	low			
Gypsum me/100 gm.	.16	.10	.14			
Organic matter, percent						
SATURATION EXTRACT						
Conductivity EC x 10^3 @ 25°C	.767	.489	.319			
pH	8.1	8.5	8.4			
Dissolved solids p.p.m.	475	280	234			
Boron p.p.m.						
Carbonate me./l		.46	.35			
Bicarbonate me./l	7.24	4.58	2.61			
Chloride me./l	.63	.12	.25			
Sulfate me./l	1.00	.45	.33			
Calcium me./l	5.00	3.30	1.83			
Magnesium me./l	2.60	2.10	1.41			
Sodium me./l	.28	.30	.36			
Potassium me./l	1.27	.10	.02			
S.A.R.	.1	.12	.3			
EXCHANGE RELATIONS						
Total sodium me./100 gm.	.23	.23	.25			
Soluble sodium me./100 gm.	.01	.01	.02			
Exchangeable sodium me./100 gm.	.22	.22	.23			
Cation exchange capacity me./100 gm.	27.31	27.00	25.63			
Exchangeable sodium percent	.8	.8	.9			
PARTICLE SIZE ANALYSIS						
Percent > 2 m.m.						
Percent sand .05-2 m.m.	34.0	30.8	23.6			
Percent silt .002-.05 m.m.	42.0	42.2	39.2			
Percent clay < .002 m.m.	24.0	27.0	37.2			
Texture	loam	loam	Clay loam			

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

TP-V

VEGETATION–SOIL DESCRIPTION

1. State Colo	2. District Craig	3. Planning Unit WF	4 Vegetation–Soil Unit Sage, serviceberry, grass	5. Soil Map Symbol 6060	6. Surname McCoy, Brown, Bona, Masterson	7. Date 9 mo 10 yr 74
8. Area --	9. County Moffat	10. Location Sec. 4, T. 3N, R. 93W	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock Shale & sandstone

15. Formation Name Mesaverde	16. Surface Conditions (percent) Stone -- Rock 35	17. Land Conditions Alkaline Saline Water table	18. Landform Rolling Hills
19. Slope (percent) 8 ☐ Single [C] Complex	20. Aspect NW 21. Elevation	22. Present Erosion Slight Type Wind and water SSF 20 Class 1	23. Hydrologic Group –

24. Precipitation (in) 18 1st , 2nd , 3rd , 4th	25. Temperature 60 Air -- Soil	26. Frost-free Days 128 > 28°	27. Drainage Class Moderate well drained	28. Infiltration Moderate	29. Percolation Slow	30. ERD 16 in	31. AWC Medium in

32. HORIZON	33. THICKNESS (IN)	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1:5	42. BOUNDARY
A	0-4	10yr 7/6 D 10yr 5/6 M	10yr 6/3	Loam	1-f - Cr	Sh - D fr - M	-	3f-vf ran	-	8.4	Clear & smooth
C_1	4-6	10yr 5/6 D 10yr 5/6 M	-	Sandstone	-	Vh - D Vh - M	-	2f-M ran	100	8.8	Abrupt & smooth
C_{2ca}	6-16	10yr 7/2 D 10yr 6/3 M	2.5y 7/2	Loam	1-M-sbk	Sh - D fr - M	-	2 M ver	-	9.0	Clear & wavy
R	16-34	10yr 8/2 D 10yr 5/4 M	10yr 7/6	Sandstone		Vh - D Vh - M	-	1-M ver	100	-	Top-abrupt bottom - defused & wavy

Note
Below 34", shale with thin stratified lenses of sandstone

Table III-10

TP-V

43. Allotment	44. Pasture	45. Acres ______
46. Surname ______________________	47. Date __ mon __ yr	48. Transect No. ________

TRANSECT HITS

VEGETATION		OVERSTORY * 49 BASAL	OVERSTORY * 50 CANOPY	51. COVER (percent)	UNDERSTORY 52 BASAL	UNDERSTORY 53 CANOPY	UNDERSTORY 54 TOTAL	55. TOTAL HITS	56. COMPOSITION (percent)
GRASSES	Blue grass			10					
FORBS									
WOODY SPECIES	Sage			20					
	Serviceberry			30					
SUBTOTAL				60					100
LITTER† BASAL	P								
	NP								
LITTER† CANOPY	P								
	NP								
ROCK SMALL	1/8" to 2"								
ROCK LARGE	2"+								
Bare ground									
TOTAL				100					

57. VEGETATION	58. LITTER	ROCK 59 SMALL	ROCK 60 LARGE	61. BARE GROUND	62. TOTAL COVER
60	20		10	10	100

---

* *Record Litter, Rock, and Bare ground in Column 49 when they are not under a canopy*

† *P, persistent; NP, nonpersistent; last less than 2 years*

GPO 832-491

TABLE III-11

ANALYSIS OF SOILS

Project USBR - BLM Coal Overburden

Collected by J. McCoy - C.D. Brown Date Received 9/13/74

Analyzed by Hyde, Hatfield, Sory, Furneaux Date

Location and Class

Vegetation

SAMPLE						
Lab No.	95	96	97			
Field No.	TP-5	TP-5	TP-5			
Depth, inches	0-4	4-6	6-16			
Field texture	Cl. loam	Weathered Sandstone	CL. Lm. lime			
SOIL						
Saturation percentage	36.2	36.4	36.6			
pH paste	7.6	7.8	8.0			
pH, 1:5 dilution	8.4	8.8	9.0			
Insoluble carbonates	Hi	Hi	Hi			
Gypsum me/100 gm.	.40	.45	.26			
Organic matter, percent						
SATURATION EXTRACT						
Conductivity EC x 10^3 @ 25°C	.988	.650	.380			
pH	8.1	8.1	8.3			
Dissolved solids p.p.m.	870	480	240			
Boron p.p.m.						
Carbonate me./l			.17			
Bicarbonate me./l	8.27	4.99	3.33			
Chloride me./l	.39	.35	.08			
Sulfate me./l	1.25	1.24	.68			
Calcium me./l	8.50	5.52	2.61			
Magnesium me./l	1.35	1.44	1.26			
Sodium me./l	.20	.56	.21			
Potassium me./l	.62	.31	.10			
S.A.R.	.1	.3	.2			
EXCHANGE RELATIONS						
Total sodium me./100 gm.	.28	.28	.28			
Soluble sodium me./100 gm.	.01	.02	.01			
Exchangeable sodium me./100 gm.	.27	.26	.27			
Cation exchange capacity me./100 gm.	15.00	13.81	12.44			
Exchangeable sodium percent	1.8	1.9	2.2			
PARTICLE SIZE ANALYSIS						
Percent > 2 m.m.						
Percent sand .05 - 2 m.m.	45.0	34.2	31.2			
Percent silt .002 - .05 m.m.	29.0	39.0	42.0			
Percent clay < .002 m.m.	26.0	26.8	26.8			
Texture	Loam	Loam	Loam			

Shallow soils to weathered sandstone and shale are typical of Soil Unit VI.

In the study to characterize the soils, nine typical profile pits were dug, and the profile was classified in accordance with U.S. Department of Agriculture Handbook No. 18. These findings are reported on Bureau of Land Management Form 7310-9a and on a Bureau of Reclamation Form, R4-405 "Analysis of Soils." In addition to aid in the characterization of the overburden material and the soil inventory, 31 power auger holes were logged and the data recorded in Appendix A of this report.

Present Use and Evaluation

In most instances lands at the Taylor Creek site are presently used for the production of forage and cover for livestock and wildlife. Management opportunities identified in watershed conservation and development include: (1) the improvement of vegetative cover, (2) development through chemical and physical alternatives, (3) the rehabilitation of uncontrolled destruction of plants and soil, and (4) the management practices necessary for the protection of soils and vegetation. These opportunities were rated and evaluated for each soil unit in Tables III-12 to III-15 using Bureau of Land Management Forms 7310-21, 22, 23, and 26.

Table III-12
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

INTERPRETIVE RATINGS FOR SELECTED SOIL PROPERTIES AND QUALITIES

MAP SYMBOL (1)	SOIL NAME (2)	CLASS				LIMITING LAYER		EFFECTIVE ROOTING DEPTH *(in.)* (9)	AVAILABLE WATER CAPACITY *(in.)* (10)	PRECIPITATION *(in.)*		EROSION		COMPACTION HAZARD *(Class)* (15)	FREQUENCY OF FLOODING (16)	REACTION RANGE *(pH)* (17)	FROST SUSCEPTIBILITY *(Class)* (18)
		DEPTH (3)	PERMEABILITY (4)	RUNOFF (5)	DRAINAGE (6)	KIND (7)	THICKNESS (in.) (8)			ANNUAL (11)	EFFECT (12)	CONDITION (13)	SUSCEPTIBILITY (Class) (14)				
II 6020	Unnamed	Deep	Mod	Slow	Mod W.D.	CP		48	Mod	18		Slight	Slight	Mod	None	8.2	Mod
6021	Unnamed	Deep	Mod	Rap	Mod W.D.	CP		60	Mod	18		Slight	Slight	Mod	Ocal	8.0	Mod
III 6030	Unnamed	Mod Deep	Mod	Rap	Mod W.D.	Pc		37	High	18		Slight	Mod	Mod	None	7.7-9.3	Severe
IV 6040	Unnamed	Mod Deep	Mod	Rap	Mod W.D.	Pc		21	Mod	18		Slight	Mod	Mod	None	7.0-7.6	Severe
VI 6060	Unnamed	S	Slow	Rap	Mod W.D.	Pc		16	Mod	18		Slight	Mod	Mod	None	8.4-9.0	Mod

Remarks

Table III-13

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

ENGINEERING PROPERTIES OF SOILS
MEASUREMENTS AND INTERPRETATIONS

Soil unit or map symbol (I)	SOIL NAME (2)	DEPTH FROM SURFACE OF TYPICAL PROFILE *(inches)* (3)	DEPTH TO		HYDRO-LOGIC SOIL GROUP (6)	SHRINK-SWELL POTEN-TIAL (7)	CORROSIVITY	
			BED-ROCK (4)	SEASONAL HIGH WATER TABLE (inches) (5)			UNCOATED STEEL (8)	CON-CRETE (9)
II								
6020	Unnamed	0-2.5			D	Low	Low	Mod
6020	Unnamed	2.5-10			D	Mod	Mod	Low
6020	Unnamed	10-22			D	High	High	Low
6020	Unnamed	22-40			D	Mod	Mod	Low
6020	Unnamed	40-48			D	Mod	Mod	Low
6021	Unnamed	0-60			D	Low	Mod	Low
III								
6030	Unnamed	0-5			D	Low	Low	Low
6030	Unnamed	5-16			D	High	High	Low
6030	Unnamed	16-22			D	High	High	High
6030	Unnamed	22-37			D	High	High	High
IV								
6040	Unnamed	0-3.5			D	Low	Low	Low
6040	Unnamed	3.5-21			D	Low	Low	Low
6040	Unnamed	21-46			D	High	High	Low
VI								
6060	Unnamed	0-4			D	Low	Low	Low
6060	Unnamed	4-6			D	Low	Low	Low
6060	Unnamed	6-16			D	Low	Low	Low
6060	Unnamed	16-34			D	Low	Low	Low

(Continued on reverse)

Form 7310–22 (August 1973)

CLASSIFICATION			COARSE FRAC-TION (percent)	PERCENTAGE PASSING SIEVE				PERCENT		MOISTURE DENSITY		ADDI-TIONAL PROPER-TIES
				NUMBER								
USDA TEXT. (10)	UNIFIED (11)	AASHO (12)	(13)	4 (14)	10 (15)	40 (16)	200 (17)	LIQUID LIMIT (LL) (18)	PLASTI-CITY INDEX (PI) (19)	MAXIMUM DRY DENSITY (lbs./cu.ft.) (20)	OPTIMUM MOISTURE (Percent) (21)	(22)
II												
Silt loam	ML	A_4				20	80	10-25	4-7			
Silty clay loam	CL	A_7				20	80	15-30	10-20			
Clay	CH	A_7				15	85	50-65	25-35			
Clay	CL	A_7				5	95	15-30	10-25			
Silty clay	CL	A_7				10	90	15-30	10-25			
Loam	CL	A_7				25	75	15-25	10-25			
III												
Loam	CL	A_7				40	60	15-25	10-20			
Clay	CH	A_7				20	80	50-60	25-40			
Clay	CH	A_7				10	90	50-65	25-40			
Organic clay	OH					10	90					
IV												
Loam	ML-CL	A_6			10	25	65	25-29	4-7			
Loam	CL	A_7			10	20	70	15-30	10-20			
Clay loam	CH	A_7				25	75	50-60	20-30			
VI												
Loam	CL	A_7				45	55	10-15	7-10			
Sandstone		A_7						NP				
Loam	CL	A_7				30	70	10-25	15-25			
Sandstone								NP				

GENERAL INSTRUCTIONS

Soil Scientist prepares in *triplicate*. File original in District Office. Submit copies to State Office and Service Center (350). (See BLM Manual 7312)

SPECIFIC INSTRUCTIONS

(Columns not listed are self-explanatory)

Column 1 MAP SYMBOL – A tie *must* be made between the soil map and interpretive table for identification purposes.

Column 2 SOIL NAME – Enter soil name, slope, and other modifiers. If soil is not correlated, insert the word *"unnamed"*.

Column 22 ADDITIONAL PROPERTIES – Enter other soil properties that might be important to engineering.

Table III-14
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

INTERPRETIVE RATINGS FOR SOIL USES

MAP SYMBOL (1)	SOIL NAME (2)	SUITABILITY DRYLAND FARMING (3)	IRRIGATION (4)	TOPSOIL (5)	SAND/GRAVEL (6)	ROAD FILL (7)	OTHER (8)
6020	Unnamed	Fair	Poor	Good	Poor	Poor	
6021	Unnamed	Poor (Narrow Creek bottoms)	Poor	Poor	Poor	Poor	
6030	Unnamed	Fair	Poor	Poor	Poor	Poor	
6040	Unnamed	Fair	Poor	Poor	Poor	Poor	
6060	Unnamed	Poor	Poor	Poor	Poor	Poor	

(Continued on reverse)

DEGREE OF LIMITATION AND SOIL FEATURES AFFECTING														
PONDS					AREAS									
LOCATION (9)	EMBANKMENT (10)	ROAD LOCATION (11)	SHALLOW EXCAVATIONS (12)	BUILDING SITES (13)	CAMP (14)	PICNIC (15)	PLAY (16)	PATHS/ TRAILS (17)	SEPTIC TANK ABSORPTION (18)	SEWAGE LAGOONS (19)	SANITARY LANDFILL (trench) (20)	LAWNS AND GOLF FAIRWAYS (21)	LANDSCAPE PLANTINGS (22)	OTHER (23)
Mod	Mod	NA	Slight	Mod	Slight	Slight	Slight	Slight	Mod	Mod	Severe	Mod	Mod	
Mod	Mod	NA	Mod	Severe	Mod	Mod	Severe	Mod	Mod	Mod	Severe	Severe	Mod	
Mod	Mod	NA	Severe	Severe	Mod	Mod	Mod	Mod	Severe	Mod	Severe	Severe	Mod	
Severe	Severe	NA	Severe	Severe	Mod	Mod	Severe	Severe	Severe	Severe	Severe	Severe	Severe	
Severe	Severe	NA	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	

GENERAL INSTRUCTIONS

Soil Scientist and Natural Resource Specialist prepares in *triplicate*. File original in District Office. Submit copies to State Office and Service Center (350). (See BLM Manual 7312)

SPECIFIC INSTRUCTIONS

Column 1 MAP SYMBOL – A tie *must* be made between soil map and interpretive table for identification purposes.

Column 2 SOIL NAME – Enter soil name, slope, and other modifiers. If soil is not correlated, insert the word *"unnamed"*.

SUITABILITY
Columns 3 through 8 – Rate soils according to the most limiting factor.

DEGREE OF LIMITATION AND SOIL FEATURES AFFECTING
Columns 9 through 22 – Enter appropriate soil limitation rating and description. The most limiting factor determines the degree of limitation for the use.

Column 23 OTHER – Enter kind of use and rating.

Table III-15
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

WATERSHED MANAGEMENT

MEASUREMENTS AND INTERPRETATIONS

Soil Unit or MAP SYM-BOL	SOIL NAME	SOIL LIMITATIONS TO VEGETATIVE MANIPULATION AND WATERSHED TILLAGE PRACTICES MECHANICAL EQUIPMENT USAGE											POT. VEG. GROUND COVER *(Percent)*	OTHER INTER-PRE-TATION
		RANGELAND		CHAINING	CONTOUR FUR-ROWING	RIPPING	PITTING	TER-RACING	TRENCH-ING	WATERSPREADING		SEEDING		
		DRILL	DISC PLOW							CONSTRUC-TION	IRRIGA-BLE			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
II 6020	Unnamed	Slight	Slight	Mod	Slight	Slight	Slight	Slight	Slight	Slight	Fair	Slight	-	NA
6021	Unnamed	Slight	Mod	Mod	Severe	Slight	Slight	Slight	Slight	Slight	Fair	Slight	-	NA
III 6030	Unnamed	Slight	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Fair	Slight	-	NA
IV 6040	Unnamed	Mod	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Poor	Mod	-	NA
VI 6060	Unnamed	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Poor	Severe	-	NA

Remarks

Laboratory and greenhouse results

During the field characterization of the soil and overburden material, a total of 262 samples were analyzed at the Upper Colorado Region Soils Laboratory in Salt Lake City, Utah. The results of these tests have been presented in table form under the various headings throughout the body of this report and in Appendix A.

Greenhouse studies were conducted at Colorado State University on 98 samples from Bureau of Reclamation core drill holes BR-101 and 102 and auger hole Nos. 1, 3, 11, 13, 19, and 24. The greenhouse study was another screening test used to give an indication of the suitability of the soil and overburden material as a plant growth media. The study consisted of seeding western wheatgrass (Agropyron smithii var. Arriba) in each overburden sample and recording the growth response under controlled conditions. Observations taken included (1) the oven-dried weight of harvested material, (2) the amount of black leaf tips, (3) the degree of soil surface cracking, (4) the amount of salt crusting, and (5) the average plant height.

Yields on the overburden samples from the Taylor Creek site ranged from good to poor with yields on the 0- to 30-foot samples generally greater than yields on samples deeper than 30 feet. Table III-16 is a compilation of data observed at the Taylor Creek site. Methods and procedures for the greenhouse studies are included in the Appendix B.

Weathering tests were conducted on eight duplicate samples of overburden material from the Taylor Creek site.

Results of these weathering tests indicated that, in general, the freezing-thawing condition caused more weathering or breakdown than wetting-drying. This was evident by both visual examination and gradation analyses conducted on several samples after testing. These gradation analyses are summarized in Table III-17. A copy of the methods and procedure of the weathering tests is included in Appendix C.

Abbreviations used in tables

Abbreviation	Meaning	Abbreviation	Meaning
BD	Breakdown	Sat	Saturated
C	Cracking	Sc	Scouring
Cv	Cleaving	Sk	Slaking
Cy	Cycle	Sp	Slumping
F	Freeze-thaw sample	Sv	Severe
Fr	Friable	Sw	Swelling
NC	No change	v	Very
ND	Not determined	W	Wet-dry sample
P	Peeling	%	Percent
S	Slight (Slightly)		

Table III-16
Greenhouse data for Colorado site

Sample number	Depth (feet)	Pot weight (Kg)	Germination: Days after seeding for ten plants to emerge		Germination: Number of seeds germinated		Salt crust at germination	Salt crust at harvest	Harvest: Plant dry weight (gm)		Harvest: Average plant height (cm)		Black leaf tips	Soil surface cracks	Field capacity (percent)
			I	II	I	II			I	II	I	II			
S-D2- 1-74	0 - 1	2	5	5	34	34			2.50	3.07	42	39			18.7
S-D2- 2-74	1 - 3	2	5	5	34	34	1		1.90	1.85	31	34			18.4
S-D2- 3-74	3 - 4	2	7	6	35	33	2	2	1.25	1.36	28	31			20.4
S-D2- 4-74	4 - 4.8	2	6	6	30	31	2	2	1.61	1.53	27	32			18.1
S-D2- 5-74	4.8- 8	2	7	6	30	30	1		1.98	1.97	33	32			18.2
S-D2- 6-74	8 - 9	2	6	6	31	35	1	2	1.39	1.66	24	30	1		20.0
S-D2- 7-74	9 - 11	2	5	5	33	31	1		1.92	1.74	33	30			18.1
S-D2- 8-74	11 - 14	2	5	5	32	32	1		2.08	2.59	36	37			13.2
S-D2- 9-74	15.3- 17.6	2	8	*	27	*			1.73	*	29	*		1	11.9
S-D2-10-74	17.6- 33.0	2	5	7	29	32	2	2	2.57	2.20	41	37			15.9
S-D2-11-74	34.3- 47.8	2	8	9	20	25			.69	.75	24	25	3		6.8
S-D2-12-74	47.8- 55.6	2	6	6	35	35		1	1.30	1.32	28	28			14.0
S-D2-13-74	55.6- 58.5	2	8	*	24	*			1.19	*	29	*			7.6
S-D2-14-74	58.5- 64.4	2	6	5	32	32	2	2	1.46	1.66	34	32	2		11.6
S-D2-15-74	64.4- 69.8	2	5	7	31	24			1.29	1.33	29	31	2		9.5
S-D2-16-74	69.8- 85.4	2	7	8	21	20			1.01	1.10	29	29	4		6.6
S-D2-17-74	85.4- 88.2	2	7	7	24	22			.75	1.02	27	25			9.2
S-D2-18-74	88.2- 97.0	2	7	14	20	14			.97	.87	26	27			7.1
S-D2-19-74	97.0-109.2	2	7	7	28	28			1.58	1.57	34	32			10.4
S-D2-20-74	109.2-111.7	2	10	10	26	18			.71	.72	24	25	3		6.3
S-D2-21-74	111.7-116.6	2	10	12	31	25			.64	.65	23	24			10.9
S-D2-22-74	116.6-133.0	2	6	7	26	31			.67	.87	24	26			12.7
S-D2-23-74	147.6-167.3	2	7	7	30	29	1		1.92	1.71	32	31			14.3
S-D2-24-74	167.3-178.2	2	7	7	31	32			1.06	1.52	32	32			9.1
S-D2-25-74	184.0-198.5	2	7	7	22	27	1		.86	1.31	30	29	1		8.2
S-H11-1-74	0 - 1	2	5	5	33	33			2.72	2.55	39	34			15.4
S-H11-2-74	1 - 3	2	5	5	34	32			2.45	2.74	41	36			16.1
S-H11-3-74	3 - 4	2	6	10	32	34			1.21	1.41	30	30			14.7
S-H11-4-74	4 - 6	2	5	5	33	35			2.33	2.83	39	37			16.6
S-H11-5-74	6 - 7	2	10	10	25	23			.92	1.11	26	30	3		13.4
S-H11-6-74	7 - 9.5	2	5	5	35	33	1		1.86	2.35	36	37			16.1
S-H11-7-74	9.5- 12	2	7	5	29	33	1		1.42	1.82	32	35	1		13.1
S-H11-8-74	12 - 16.5	2	6	7	29	33	1		1.93	1.88	31	30			14.3
S-H11-9-74	16.5- 19	2	6	6	32	30	2	2	2.25	2.23	30	29	2	1	23.7
S-H13-1-74	0 - 1	2	6	6	32	32			2.62	2.51	38	32	1		18.3
S-H13-2-74	1 - 2	2	5	*	25	*			2.35	*	38	*	1		19.0
S-H13-3-74	2 - 3	2	7	*	31	*			1.73	*	33	*			17.2
S-H13-4-74	3 - 4	2	12	12	19	21			.81	1.03	29	30			13.1
S-H13-5-74	4 - 8	2	10	7	29	25			1.47	1.46	34	30			9.9
S-H13-6-74	9 - 10	2	5	5	26	31	1		2.52	2.69	33	37			19.1
S-H13-7-74	10 - 11.5	2	6	6	31	30			2.54	2.16	40	34	2		16.3
S-H13-8-74	11.5- 15	2	6	7	32	32		1	2.09	2.26	38	33	1		16.9
S-H13-9-74	15 - 17	2	7	6	31	32			1.66	2.05	38	35	2		12.6
S-H19-1-74	0 - 2	2	5	5	33	33	1		3.34	2.87	43	38			19.6
S-H19-2-74	2 - 4	2	5	5	32	33	1		2.19	2.82	41	41	2		15.7
S-H19-3-74	4 - 8	2	5	5	34	32	1		1.43	1.88	32	31			13.2
S-H19-4-74	8 - 9	1.5	5	*	34	*	2	2	.58	*	23	*			23.1
S-H19-5-74	9 - 10	1.5	13	10	33	28			trace	trace					10.7
S-H19-6-74	10 - 11	2	5	*	27	*	2	2	1.24	*	28	*			20.3
S-H19-7-74	11 - 14	2	5	5	35	33	1		2.61	2.66	39	28			17.9
S-H19-8-74	14 - 15	2	5	5	18	33			3.50	3.61	43	45			20.7
S-H19-9-74	15 - 16	2	7	*	24	*			1.67	*	30	*			14.8

* Sample enough for only one pot.

Table III-17
Weathering tests
Core samples from Craig, Colo.

Laboratory sample numbers	Sample identification	Rock classification	Number of pieces	Remarks		
				Cycles 1-10	Cycles 11-20	Cycles 21-30
C-1F	DH 102	Sandstone	1	NC	S Sc 16 Cy	C 25 Cy; % % BD 20.9
C-1W	Depth 14.0' - 15.2'		1	NC	NC	NC; % BD 0
C-2F	DH 102	Mudstone and shale	1	NC	S Sc 16 Cy	Sc 25 Cy; % Bd 5
C-2W	Depth 15.2' - 17.5'		1	NC	S Sk 16 Cy	Sk 22 Cy; % BD 26.4
C-3F	DH 102	Mudstone, sandstone, and shale	1	SC 3 Cy; C 3 Cy	S Sat 15 Cy; Sv C 18 Cy	BD 26 Cy; % BD 100
C-3W	Depth 17.5' - 33.0'		2	C 6 Cy	Sv C 16 Cy; S Sk 19 Cy	Sk 21 Cy; Sv Sk 30 Cy; % BD 100
C-4F	DH 102	Sandstone	1	NC	S Sc 16 Cy	Sc 22 Cy; Fr 26 Cy; % BD 75.3
C-4W	Depth 34.2' - 47.7'		1	NC	NC	NC; % BD 0

Potential plant growing material

Soil

The soils in Units II and III comprise 46 percent of the study site and are well suited for stockpiling and replacement on surfaced, mined, or disturbed lands.

Soil characteristics as indicated by the physical and chemical data show that no adverse or harmful effects would be expected on adaptable vegetative types. Chemical properties of the soils indicate that salinity and sodicity are not a problem. Their permeability rates vary from slow to moderate (0.06 to 0.60 inch per hour). These rates are high enough to limit runoff and erosion damage from low intensity storms. High intensity storms, however, do occur in this area and at times could be a problem during the early stages of reclamation. The available water-holding capacity depends primarily on depth of soil, texture, organic matter, and coarse fragments. The estimated range is low to moderately high (3 to 9 inches per effective soil depth).

Subsoils are well developed, textures are predominantly clays, and structural development consists of strong subangular blocky to strong coarse prismatic. They are nonsaline with most electrical conductivities below 4 millimhos per centimeter.

The soils in Units IV and VI comprise 54 percent of the study site. Their soil and topographic features preclude their use as stockpiled material for reclamation of surface-disturbed areas. During mining operations, however, these areas will become cast overburden and mixed with underlying material that could be utilized as plant-growing media with little or no adverse effects.

Overburden

The geologic overburden will, with time, weather into a suitable plant medium. Screening tests show no toxic material exists except for two layers of shale sandstone material, one above and one below a prominent coal seam.

This material is located in Bureau of Reclamation core hole No. BR-102 at the 116.6- to 133-foot depth and from 147.6- to 167.3-foot depth. Correlation with greenhouse studies indicates little difference between these layers and other layers within the profile. This would indicate that these layers could be mixed and placed during the mining operations in such a way that they would be of little significance during reclamation.

The successful reclamation of surface-mined lands at the Taylor Creek site will depend upon an environmental awareness and an intensive

and coordinated effort by the industry to comply with Federal and State regulations.

Techniques, procedures, and standards

Techniques, procedures, and standards were developed during the course of this study by personnel of the Bureau of Reclamation, Bureau of Land Management, and the U.S. Geological Survey. They are general in scope and were developed using the techniques, procedures, and standards established by the Bureau of Land Management's Soil Manual (7312 Series) and other data, the Bureau of Reclamation's Soil Classification Manual, Volume 5, and other publications, and the Soil Conservation Service's Soil Taxonomy Manual (October 1973). Agriculture Handbooks Nos. 18 and 60 were also used in the identification and description of the soils and in establishing and interpreting soil chemical data.

"The Ecological Basis for Land Use Planning" by the Ontario Department of Lands and Forests was helpful in establishing the land use standards used in this study.

Field Procedures

The soil and overburden mapping and investigation work were accomplished by utilizing aerial photographs with a scale of 1 inch equals 660 feet for the base maps. The exploratory work was accomplished by using a truck-mounted 18-inch-diameter power auger (Texoma) with a depth capacity of 25 feet.

Core drilling was accomplished by using a Sprague and Henwood skid-mounted core drill. Core recovery was 99 percent with coal samples being retained by the site lessee, W.R. Grace and Company, for analysis. During the core drilling investigations two deep holes were completed, DH-101 to a depth of 217 feet and DH-102 to a depth of 198.5 feet. NX casing was used and the cores logged and boxed by the Bureau of Reclamation's Assistant Regional Geologist.

Power auger holes were dug utilizing the Texoma auger and a field crew of three, including the operator, drill foreman, and a soil scientist from the Bureau of Reclamation.

Soil samples were taken and sacked in waterproof bags. The soil profile was logged as the hole was being dug. The samples were analyzed in the Regional Soils Laboratory at Salt Lake City, Utah.

Selected samples from the two core drill holes were sampled and sent to Colorado State University for greenhouse studies. Each of these samples consisted of 500 grams selected in duplicate and planted with western wheatgrass. Growth and dry weight comparisons were made with plants grown on a control-soil sample.

Truck-mounted, power soil auger (Texoma) used in overburden exploration.

In addition to the 30 power auger holes and the two deep core drill holes, nine test pits approximately 3 feet wide by 4 feet long by about 5 feet deep were excavated by the Texoma auger and the soil characteristics described according to Bureau of Land Management Standard Form 7310-9a. Samples were collected from these typical soil profile pits at each horizon for soil analysis by the Regional Laboratory.

The method used to determine the location of these drill sites and test pits was to cover the area systematically, being aware of the geology, general topography of the country, obvious soil changes, vegetative cover, and the study of previous holes drilled and logged by W.R. Grace and Company.

The soil scientist was acquainted with the procedure of obtaining good representative soil samples, so as to avoid contamination of one horizon with another.

Laboratory Procedures

Soil laboratory methods and procedures used in the screening test for the overburden material at the site were selected by the Bureau of Reclamation in cooperation with the Bureau of Land Management and others. Analysis consisted of ten screening tests conducted on 230 overburden samples. These data are presented in Appendix A.

Detailed soil analysis utilizing 13 tests were conducted on 32 samples from the typical profile pits. Soil physical properties from these analyses are recorded on Bureau of Land Management Form 7310-19. The soil chemical properties are presented in Table III-18 on Form 7310-20 and in Appendix A.

Methods and procedures used in testing soils and overburden are found in Bureau of Reclamation Instructions, Series 510 part 517, "Laboratory Procedures," U.S. Department of Agriculture Handbook 60, and Part 2 Agronomy 9, "Methods of Soil Analysis."

Vegetation, Soil-Moisture-Retention Characteristics, and Soil Erodibility

Vegetation

The Taylor Creek site is at the transition between the big sagebrush type in the lower portion and mountain brush in the upper portion. Because the site is near the upper limit of big sagebrush, sage is found on dryer sites such as south-facing slopes and fine-textured uplands. Mountain brush occupies about two-thirds of the area but is most abundant on north-facing slopes. Types of minor importance include Utah juniper on a dry, rocky bench just north of the Streeter Mine and a few stands of quaking aspen in moist valley bottoms, usually near springs.

Vegetation types and dominant species are shown on Figure III-6 and in Table III-19. The main grasses found in the big sagebrush type are western wheatgrass and Kentucky bluegrass. On rocky, south-facing slopes, bluebunch wheatgrass becomes an important associate.

The most common shrub in the area mapped is serviceberry and it is usually associated with Gambel's oak. Gambel's oak becomes more abundant with an increase in moisture near slope bottoms and is also found in isolated pure stands, Habitat differences cause different degrees of dominance by the three shrubs (big sagebrush, serviceberry, and Gambel's oak) and are expressed in the units shown on Figure III-6. Vegetation and soil sampling was restricted to five of the eleven mapped vegetation types where dominance by species was clearly expressed.

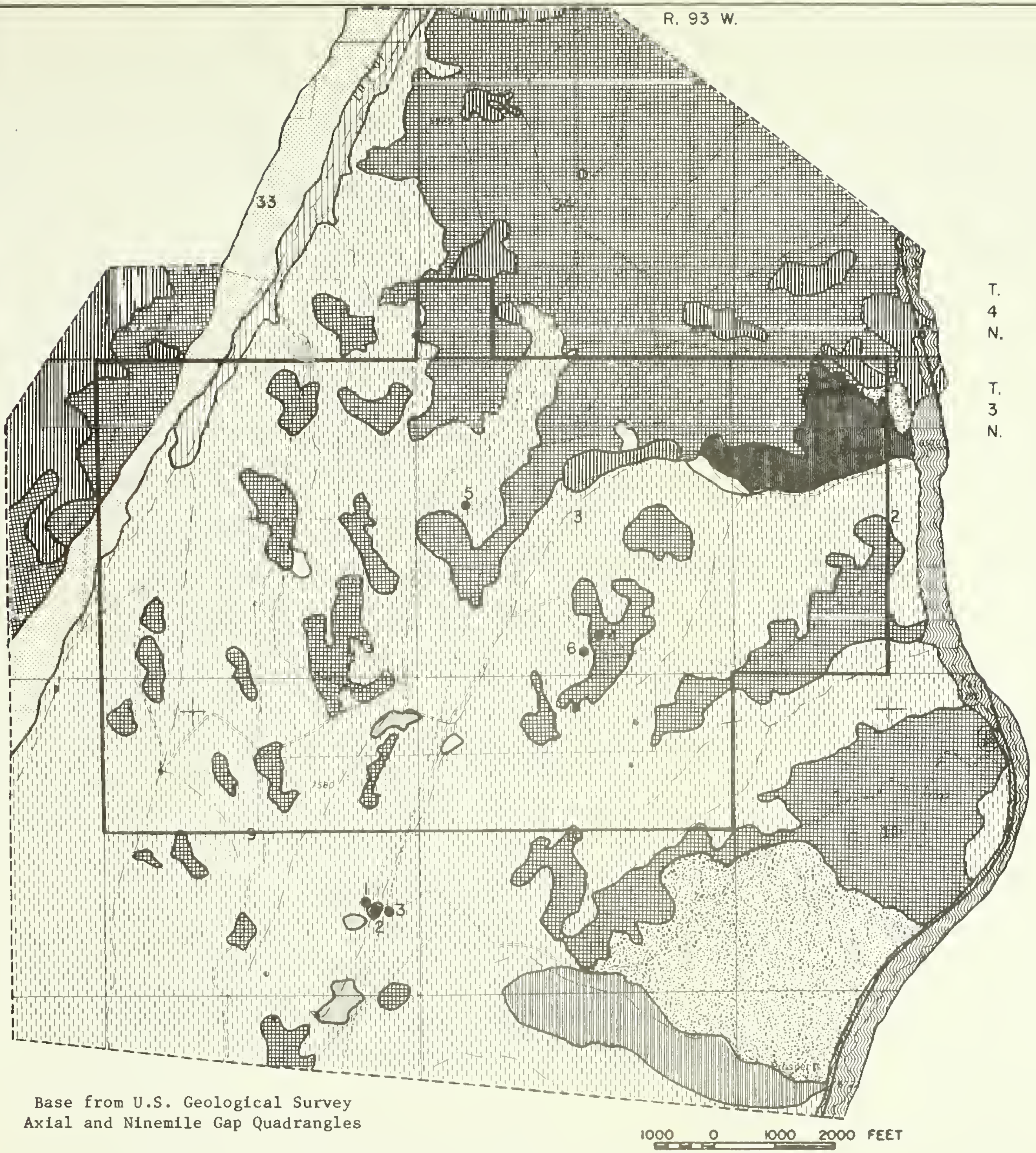
Table III-18
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

SOIL CHEMICAL PROPERTIES

SOIL NAME, SAMPLE NUMBER, AND LOCATION	DEPTH FROM SURFACE (in.)	HORIZON	SOIL REACTION (water 1:1) (pH)	ORGANIC MATTER				EXTRACTIBLE CATIONS (Meq/100gm)				CATION EXCHANGE CAPACITY (NH_4OAc) (ME/100g)	BASE SATURATION (NH_4OHc) (%)	ELECTRICAL CONDUCTIVITY ECX10^3 (mmhos/cm)	EXCHANGEABLE SOOIUM (ESP) (%)	SODIUM AOSORPTION RATIO (SAR)	EXTRACTIBLE ANIONS (Meq/100gm)			
				CARBON	TOTAL NITROGEN (%)	CARBON NITROGEN RATIO (C/N)	FREE IRON (Fe_2O_3) (%)	Ca	Mg	Na	K						$CO_3^=$	HCO_3^-	$SO_4^=$	Cl^-
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
TP - 1	0-3.5							5.00	2 60	.28	1.27	27 31		.767	.8	.1		7.24	1.00	.63
	3.5-21							3,30	2.10	.30	.10	27.00		.489	.8	.12	.46	4.58	.45	.12
	21-46							1.83	1.41	.36	.02	25.63		.319	.9	.3	.35	2.61	.33	.25
TP - 2	0-60							1.83	.75	.18	.91	28.75		.341	.8	.2		3.24		.29
TP - 3	0-11.5							3.52	2.04	.32	.94	10.69		.591	1.8	.2		5.57	1/ 96	.29
	11.5-33.7							1.60	3.12	1.80	.08	34.31		.565	1.8	1.2	.61	3.81	2.32	.10
	33.7-48							26.3	46.8	10 5	.28	68.00		.510	1.8	1.7	.08	4.73	75,5	.25
	48-60							12.3	39.5	15.8	.48	33,25		4.52	3.1	3.1	.08	4.98	60.0	1.23
TP - 4	0-32							3.06	1.47	.24	.05	28.63		.427	1.0	.2	.67	3.06	1 41	.05
	32-36							2.36	1.22	.22	.03	24.25		.345	1.3	.2	.40	2.80	.60	.24
	36-48							2.31	1.83	.39	.04	16.38		.405	1.4	.3	.48	2.94	.72	.41
TP - 5	0-4							8.50	1.35	.20	.62	15.00		.988	1.8	.1		8.27	1.25	.39
	4-6							5.52	1.44	.56	.31	13.81		.650	1,9	.3		4.99	1.24	.35
	6-16							2.61	1.26	.21	.10	12.44		.380	2.2	.2	.17	3.33	.68	.08
TP - 6	0-2							13.2	4.00	.70	1.26	30.56		1.60	.9	.2		12.02	4.02	2.72
	2-4							10.2	3.50	.30	.50	30.63		1.25	.9	.1		8.89	2.60	1.16
	4-28							1.87	1.83	.33	.04	29.50		.369	1.6	.2	.32	2.68	.87	.24
	28-60							.78	2.16	2.55	.06	23.81		.492	3.3	2.1	.74	3.04	1.08	.45
TP - 7	0-2							12.3	2.00	.30	.68	24.06		1.20	1.6	.1		12.4	1.96	.29
	2-11							5.45	1.60	.20	.12	26.75		6.62	1.1	.1		5.52	1/1.60	.25
	11-23							2.38	1.02	.18	.03	29.25		.372	1.6	.1		3.09	.45	.10
	23-29							2.68	1.66	.22	.03	21.44		.400	2.1	.1	.50	3.04	.74	.16
	29-36							2.14	2.64	.36	.03	15.19		.450	3.1	.2	.48	3.41	.80	.16
TP - 8	0-5							4.41	4.89	1.38	.99	21.38		.963	1.6	.6		9.41	1.48	.78
	5-16							1.83	4.26	4.11	.20	35.13		.883	2.4	2.3	1.83	6.42	1.55	.29
	16-22							5.40	13.0	18.6	.11	37.75		2.83	6.5	6.1	.43	3.60	30.49	1.02
	22-37							24.0	74.5	56.0	.30	51.75		9.51	6.0	8.8		4.20	143.6	7.84
TP - 9	0-2.5							6.04	2.32	.48	1.42	26.81		.929	1.0	.2		6.30	3.58	.44
	2.5-10							6.48	3.12	.28	.67	26.75		.975	1.0	.1		7.91	1.69	.39
	10-22							2.40	2.10	.24	.11	44.75		.420	.5	.2	.42	3.58	.74	.07
	22-40							2.02	1.38	.36	.03	35.00		.354	1.3	.3		3.12	.41	.15
	40-48							1.40	1.72	.68	.03	27.94		.352	1.7	.5		2.90	.72	.02

Remarks 1/ CALCULATED — NOT ENOUGH EXTRACT

Form 7310–20 (August 1973)



Base from U.S. Geological Survey
Axial and Ninemile Gap Quadrangles

Explanation

▥ Serviceberry-Gambel's oak type covers more than half the upper portion of the area. Understory species include Kentucky bluegrass, western wheatgrass, and Idaho fescue.

▦ Big sagebrush--covers the lower one-third of the area and is present in scattered stands in the upper two-thirds. Associated species include western wheatgrass and Kentucky bluegrass.

░ Serviceberry-Big sagebrush. Associated species include western wheatgrass and Kentucky bluegrass.

■ Utah juniper-Big sagebrush. Associated species include bluebunch wheatgrass, serviceberry, and Douglas rabbitbrush.

▥ Serviceberry. Where present in pure stands associated species include Idaho fescue, big sagebrush, and western wheatgrass.

░ Big sagebrush-Serviceberry-Bluebunch wheatgrass. Present on rocky southern exposures.

▥ Big sagebrush-Kentucky bluegrass. This type occurs on floodplains often associated with willows.

▨ Hay meadows.

▥ Gambel's oak-Serviceberry. Gambel's oak replaces serviceberry as the dominant on lower portions of north-facing slopes.

▩ Quaking aspen. Type occurs in isolated stands on floodplains or near springs at higher altitudes in the area. Kentucky bluegrass is the main understory species.

☐ Gambel's oak. Occasionally present as pure stands.

● 2 Sampling site locations

—— Study site boundary

- - - Boundary of mapped area

VEGETATION MAP OF THE TAYLOR CREEK EMRIA STUDY SITE, COLORADO - 1974

Figure III-6

Table III-19

Percentage aerial cover, mulch, bare, and rock for the vegetation types sampled on the Taylor Creek study site

Species		Vegetation types: Big sagebrush1/ Site numbers 1 and 4	Gambel's oak1/ Site numbers 3 and 5	Quaking aspen Site number 2	Serviceberry Site number 6	Utah juniper Site number 7
Trees						
Juniperus osteosperma	Utah juniper					24.5
Populus tremuloides	Quaking aspen			57.5		
Shrubs						
Amalanchier alnifolia	Serviceberry	0.4	5.5		47.0	1.6
Artemisia tridentata	Big sagebrush	36.2			14.8	5.0
Chrysothamnus viscidiflorus	Douglas rabbitbrush					1.5
Prunus virginiana	Chokecherry		.6			
Quercus gambellii	Gambel's oak		57.6			
Symphoricarpos oreophilus	Mountain snowberry	.5	1.0		.8	
Grasses						
Agropyron smithii	Western wheatgrass	12.2	.4		.6	
Agropyron spicatum	Bluebunch wheatgrass					7.0
Agropyron trachycaulum	Slender wheatgrass		.4			
Bromus marginatus	Mountain brome		.2			
Festuca idahoensis	Idaho fescue				14.0	
Poa pratensis	Kentucky bluegrass	7.2	13.4	19.7		
Poa secunda	Sandberg bluegrass					.8
Sitanion hystrix	Squirreltail					.8
Stipa viridula	Green needlegrass		1.1			
Forbs						
Achillea lanulosa	Yarrow	1.1	.3	.8		
Galium aparine	Bedstraw		.3			
Lupinus sp.	Lupine	2.3			.8	
Taraxicum officinale	Dandelion	.5	.3	1.2		
Wyethia amplexicaulis	Mules-ears				T	
Mulch		32.6	17.4	14.0	19.2	26.8
Bare		7.0	1.5	6.8	2.0	13.0
Rock					.8	19.0

1/ Each value is the mean value for the two sites sampled.

Most of the soil is covered by vegetation or mulch. Bare soil percentages ranged from a high of 13 percent for the juniper type to a low of 1.5 percent for the Gambel's oak type.

General soil considerations

Reclamation of surface-mined lands will be more successful and accomplished in less time if surface soils are stock piled and then replaced on the reshaped overburden. Effective use of the surface soils requires a knowledge of their moisture retention characteristic or the relationship betwen the quantity of moisture in the soil and the forces involved in retaining that moisture.

The moisture retention characteristic for a soil can be defined if two physical properties are known: (1) a measure of the surface available within a soil for adsorption of moisture as films and (2) a measure of the porosity of the soil that exists at the time for which the characteristic is to be defined.

Moisture contents may be defined on a weight basis (grams of water per gram of soil) or on a volume basis (cubic centimeters of water per cubic centimeter of soil). Conversions from weight to volume are made through multiplication by the dry bulk density of the soil.

The forces of moisture retention are defined in numerous ways. In this section of the report pF (Schofield, 1935), which is defined as the common logarithm of the height in centimeters of a column of water that requires an equivalent force to support it, will be used to simplify computations and permit visualization of the forces as physical dimensions.

For equilibrium conditions a pF of 1 represents the retention force at a height of 10 centimeters above a water table. At 100 centimeters above a water table the stress would be pF 2, and at 1,000 centimeters the equilibrium stress would be pF 3.

McQueen and Miller (1974) described a model for synthesizing the soil moisture characteristic from limited data. The curve is divided into segments and a separate mechanism of moisture retention determines each segment. For the range of retention forces from pF 2.5 to 5, moisture is retained as films on particle surfaces by molecular adsorptive forces that vary inversely with a power of the film thickness. This segment of the characteristic is a straight line intersecting the zero moisture content axis at pF 6.25 and passing through any valid pF versus moisture-content data points that are known.

For retention forces greater than pF 5, the moisture is adsorbed to surfaces in a pseudomolecular structure and the moisture characteristic is cyclic. It can be approximated, however, by a straight line between the zero moisture content axis at pF 7 and the adsorbed segment at pF 5.

For moisture retention forces less than pF 2.9, surface tension forces may add additional moisture in the form of capillary water bodies to the moisture retained as adsorbed films. This capillary segment of the soil moisture characteristic is unstable because of alterations in pore-geometry and the effects of a hysteresis loop, so it can only be defined in terms of limits or ranges. The probable configuration, however, can be predicted for given sets of conditions.

Synthesis of a typical soil-moisture characteristic is illustrated in Figure III-7. The adsorbed water segment is defined from one or more data points. In this report all retention data were obtained with the wide range method of McQueen and Miller (1968) but any valid data could be used. The intercept of the adsorbed water segment at pF 6.25 has been established statistically from a large mass of data and should be considered valid for most soils. Structured water (the segment above pF 5) can usually be removed from a soil profile only by evaporation near the soil surface so it need not be considered when computing transpiration. The adsorbed moisture segment is extended to the zero pF axis to indicate the computation for AMC (the maximum adsorbed moisture at a stress of pF zero).

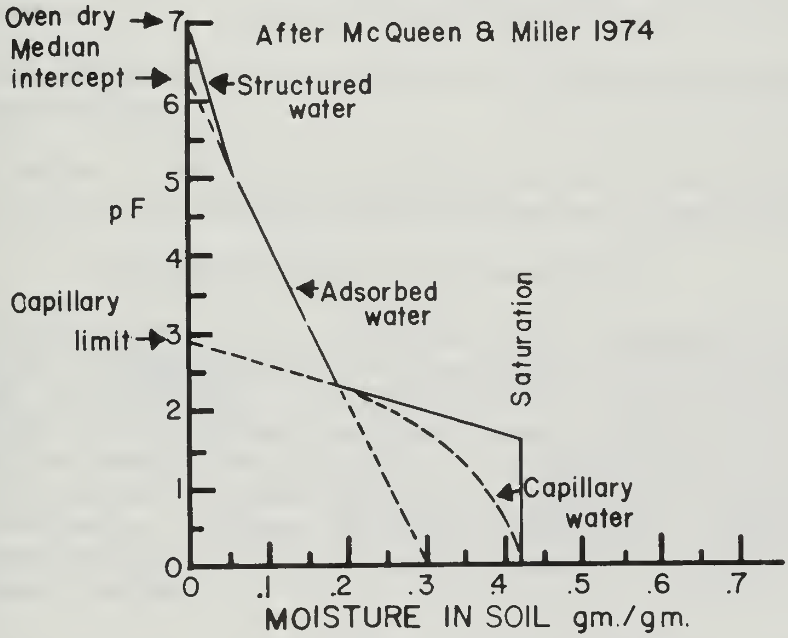


Figure III-7. A typical soil-moisture characteristic for a soil.

Soil sampling procedures and data presentation including discussions and sample computations for this phase of the report are presented in Appendix D.

Summary and inferences from the data

Selected parameters are summarized by soil horizon and by profiles and presented as averages in Table III-20. On the basis of these data some conclusions and suggestions can be made.

1. Erosion may be a problem in this study area, and the data indicated that these soils should be protected by surface treatments such as contour furrowing. Soils with EK values less than 0.4 are not considered as highly erodible soils. EK values greater than 0.5 are erodible soils. Infiltration rates are high enough to limit runoff and erosion damage from low intensity storms, but high intensity storms occur in this area. Compaction of these soils would decrease infiltration rates and increase runoff, which would result in increased erosion.

2. The soils of this area have a wide range of moisture retention capabilities that correlate with the type of vegetation and the density of cover. Arid land species may facilitate revegetation, but other species may survive on the moisture provided by the prevailing climate patterns.

3. Saline problems are not indicated in the data from the sites sampled.

4. The soils of site 4 may be mixed with the soils of site 6 or site 7 for better moisture retention characteristics.

Potential species for revegetation

Although it is assumed that the land will be returned to livestock and wildlife use following mining, the possibility of dry land wheat production should be mentioned. If the final land shape is sufficiently leveled to permit farm machinery use and topsoil plus subsoil is restored, the area receives enough precipitation for successful dry land farming. Such use would produce more food for human consumption than is possible from native vegetation. Present alluvial bottoms and colluvial lower slopes have deep organic soils that could be used to provide a satisfactory plant growth medium.

Continued use of the area for both livestock and game requires that both herbaceous and woody species be considered for reseeding. Species listed on page 61 have a potential for dual-use seeding.

Table III-20
Horizon and profile averages of hydrologic data for soils of the Taylor Creek study site

Site	Horizon	Depth (cm)	pF	M	SMC	AMC	ΔM (cc/cc)	Volume (weight)	M use (cm)	EK	TR	IR	EC	Natural cover	Plant stress	RC	S.T. requirement
1	1	60	4.37	0.104	0.421	0.350	0.137	1.22	8.19	0.421	0.770	0.237	0.503			3	3
	2	120	3.99	.133	.413	.369	.177	1.50	5.31	.433	.714	.280	.565			4	3
	3	280	3.79	.153	.443	.390	.205	1.64	6.55	.451	.707	.367	.690			4	3
	P		3.96	.138	.432	.377		1.52	20.05	.441	.722	.321	.632	60.4	4.49	4	3
2	1	70	4.19	.108	.465	.344	.124	1.13	8.71	.779	.719	3.555	.378			3	2
	2	130	3.67	.115	.398	.280	.134	1.49	4.00	.631	.778	1.622	.321			3	2
	3	200	3.41	.094	.285	.206	.108	1.64	1.51	.613	.775	1.237	.241			2	2
	P		3.76	.105	.382	.276		1.42	14.22	.676	.756	2.164	.313	79.2	4.42	3	2
3	1	50	4.22	.121	.487	.374	.104	.87	5.21	.426	.714	.362	.495			4	3
	2	100	3.88	.122	.394	.322	.163	1.58	4.07	.415	.790	.225	.559			3	3
	3	250	3.56	.129	.401	.299	.144	1.50	4.31	.627	.829	1.900	.664			3	2
	P		3.76	.126	.418	.319		1.39	13.59	.541	.797	1.230	.607	81.1	4.50	3	2
4	1	30	4.22	.170	.528	.542	.213	1.23	6.40	.428	.576	.375	.953			5	3
	2	60	4.41	.158	.522	.536	.244	1.42	3.65	.504	.715	.649	.876			5	3
	3	100	4.31	.191	.528	.684	.365	1.67	2.92	.638	.661	2.654	.529			5	3
	P		4.31	.175	.526	.597		1.47	12.97	.535	.652	1.129	.760	56.2	4.41	5	3
5	1	30	3.97	.134	.491	.370	.138	1.17	4.16	.409	.737	.221	.592			4	2
	2	80	4.44	.152	.502	.526	.263	1.56	6.56	.539	.506	.948	.827			5	2
	3	120	4.27	.115	.486	.366	.193	1.65	1.55	.529	.690	.854	.572		4.31	4	2
	P		4.27	.135	.494	.433		1.49	12.27	.503	.625	.735	.683	78.0	4.49	4	2
6	1	60	3.98	.092	.472	.257	.087	1.06	5.23	.399	.735	.237	.416			3	2
	2	110	4.15	.076	.334	.227	.107	1.47	2.67	.489	.742	.458	.280			2	2
	3	150	3.94	.047	.239	.128	.069	1.69	.55	.536	.585	.603	.177			1	2
	P		4.03	.075	.364	.213		1.37	8.45	.466	.697	.409	.307	88.5	4.52	2	2
7	1	20	4.45	.070	.351	.244	.110	1.41	2.20	1.000	.481	5.289	.410			2	2
	2	60	4.40	.042	.290	.140	.084	1.88	1.68	.805	.561	2.736	.230			2	2
	3	110	4.34	.083	.411	.270	.154	1.78	1.54	.516	.681	.846	.433		4.49	2	2
	P		4.38	.066	.356	.218		1.75	5.42	.709	.601	2.341	.355	40.6	4.54	2	2

H - Hydrologically defined horizons; the 1 horizon usually corresponds to the A horizon and the 2 to the B horizon, and the 3 to the B-2 horizon.

P - Profile values.

Depth cm - Depth in contrimeters to the bottom of the soil horizon or the maximum depth sampled.

pF - Average moisture retention force when sampled. Logarithm of the height in centimeters of a column of water requiring an equivalent force to support it.

M - Average moisture content when sampled.

SMC - Average saturating moisture capacity.

AMC - Average adsorbed moisture capacity.

ΔM - Moisture use between field capacity and ultimate plant stress expressed as volume ratio.

Vol. wt. - Average volume weight of soil.

M Use - Computed moisture depletion for horizon, profile value is the sum of the horizon.

EK - Average erodibility constant.

TR - Average transportability ratio. Portion of soil particles passing a 0.25 mm sieve.

IR - Average minimum computed infiltration rate.

EC - Electrical conductivity of saturated paste.

Nat. cov. - Natural cover of live vegetation.

Plant stress - Average pF measured in plant material using pressure Bomb technique--where two figures are given, two species of plants were measured.

RC - Revegetation textured classification.
1 - Coarse soil requires irrigation.
2 - Marginal sandy loam soil.
3 - Optimum soil texture.
4 - Marginal clay loam soil.
5 - Clay soils require surface treatment.

ST req. - Surface treatment requirement such as Arcadia contour furrowing.
1 - Probably little benefit.
2 - Beneficial for erosion control.
3 - Required for vegetation establishment.

Grasses:	Fairway crested wheatgrass	(*Agropyron cristatum*)
	Standard crested wheatgrass	(*Agropyron desertorum*)
	Western wheatgrass	(*Agropyron smithii*)
	Intermediate wheatgrass	(*Agropyron intermedium*)
	Pubescent wheatgrass	(*Agropyron tricophorum*)
	Slender wheatgrass	(*Agropyron trachycaulum*
	Bluebunch wheatgrass	(*Agropyron spicatum*)
	Russian wildrye	(*Elymus junceus*)
	Smooth bromegrass	(*Bromus inermis*)
	Idaho fescue	(*Festuca idahoensis*)
Forbs:	Alfalfa (rambler, nomad, or ladak)	(*Medicago sativa*)
	Chickpea milkvetch	(*Astragalus cicer*)
	Sicklepod milkvetch	(*Astragalus falcatus*)
	Yellow sweetclover	(*Melilotus officinale*)
	Arrowleaf balsamroot	(*Balsamorhiza sagittata*)
	Small burnet	(*Sanguisorba minor*)
Shrubs:	Antilope bitterbrush	(*Purshia tridentata*)
	Cliffrose	(*Cowania mexicana*)
	Serviceberry	(*Amalanchier alnifolia*)
	Birchleaf mountain mahogany	(*Cercocarpus montanus*)
	Woods rose	(*Rosa woodsii*)
	Golden current	(*Ribes aureum*)
	Gambel's oak	(*Quercus gambellii*)
	Mountain snowberry	(*Symphoricarpos oreophilus*)

A possible method of revegetation that has not been tried but may be feasible could be the following: after the initial cut is made and initial land shaping is accomplished, heavy-duty front loaders or similar equipment could be used to move sections of soil with native vegetation intact to the newly shaped surface. Such a procedure would retain the native vegetation and soil, and no seeding expense would be incurred. The process described above could be continuous with land being reclaimed as the cut for coal extraction advances over the land surface.

Study-Site Hydrology and Water Supply

Surface water

Estimated Annual Runoff and Peak Flows

Data for determination of mean annual runoff and peak flows of Wilson, Taylor, Streeter, and Good Spring Creeks are extremely limited. The only streamflow records for these streams are for the period October to December 1974 for gaging stations on Wilson Creek near Axial, Colo., and Good Spring Creek at Axial, Colo. The drainage basins and the locations

of these gaging stations are shown in Figure III-8. Analysis of this short period of record shows an average base flow of about 1 cubic foot per second (c.f.s.) (0.02832 m^3/s) for both gage sites.

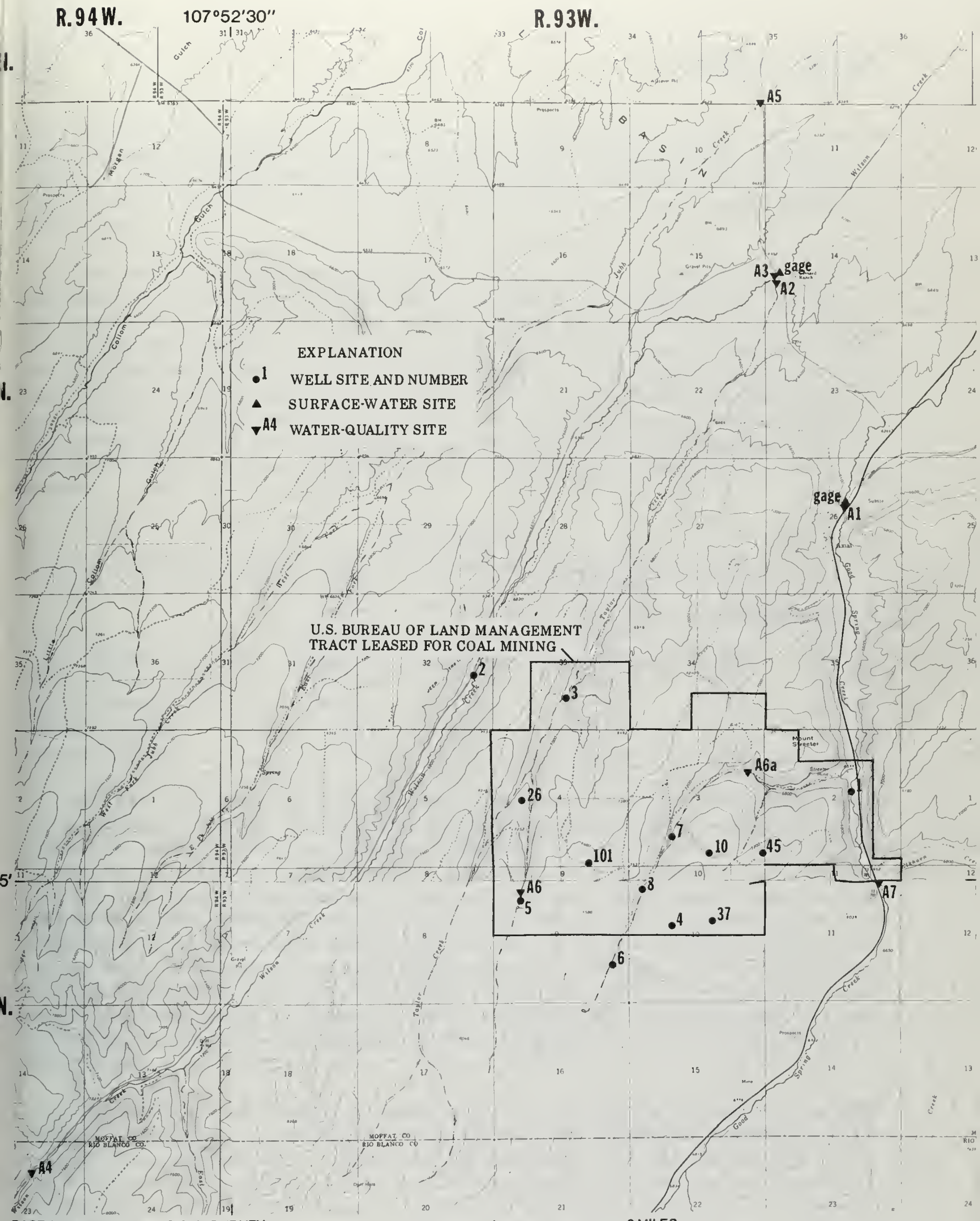
Because of the runoff data constraints, the mean annual runoff for the four basins was estimated using a water-balance procedure described by Wymore (1974). A water balance was computed by this procedure using estimates of precipitation, available water-holding capacity of soils, potential evapotranspiration, and actual evapotranspiration by elevation zones for the major vegetation types in the basins. Evapotranspiration within elevation zones was also adjusted for differences in slope and aspect.

No precipitation data have been collected within the basins. Precipitation data are available, however, for climatic stations at Meeker and Hamilton, Colo. A precipitation map of Colorado published by the U.S. Weather Bureau (1960) indicates that the Meeker data may be more representative of average precipitation conditions on the basins than the Hamilton data. The Meeker data were, therefore, used in the water balance and were adjusted for elevation differences between Meeker and basin sites. Adjustment factors used were those developed by Wymore (1974). The mean monthly and mean annual precipitation for Meeker 1941-73 is shown below.

Mean monthly and mean annual precipitation for Meeker, Colo., 1941-73

Month	Precipitation (inches)
January	1.17
February	1.07
March	1.39
April	1.65
May	1.47
June	1.45
July	1.43
August	1.92
September	1.29
October	1.52
November	1.14
December	1.39
Annual	16.89

Available water-holding capacities of soils for major vegetation types were determined from Wymore (1974) and from data obtained from R. F. Miller, I. S. McQueen, and F. A. Branson (personal communication, 1974). Potential evapotranspiration was computed using a technique described by Wymore (1974) which requires mean monthly solar-radiation and air-temperature data. The solar-radiation data were obtained from Grand Junction, Colo., 86 miles (138 km) southwest. The air-temperature data were obtained from the climatic station at Meeker, Colo. Air-temperature


R.94W.
107°52'30"
R.93W.
EXPLANATION
● 1 WELL SITE AND NUMBER
▲ SURFACE-WATER SITE
▼ A4 WATER-QUALITY SITE
U.S. BUREAU OF LAND MANAGEMENT TRACT LEASED FOR COAL MINING
A1
A2
A3
A4
A5
A6
A6a
A7
gage
gage
1
2
3
4
5
6
7
8
10
26
37
45
101
Mount Streeter
Wilson Creek
Good Spring Creek
Taylor Creek
Jubb Creek
Morgan Gulch
Collom Gulch
West Fork
East Fork
Axial
BASIN
Prospects
Gravel Pits
MOFFAT CO
RIO BLANCO CO
0 1 2 MILES
0 1 2 KILOMETRES

BASE FROM U.S. GEOLOGICAL SURVEY
1:24,000 EASTON GULCH, AXIAL,
DEVIL S HOLE GULCH, AND
NINEMILE GAP, 1966

FIGURE III-8 – INDEX MAP OF STREAMS AND SAMPLING SITES.

data were adjusted for differences in elevation between Meeker and the basin sites. Adjustment factors used were those developed by Wymore (1974). Actual evapotranspiration was computed as a function of potential evapotranspiration, precipitation, vegetation type, and available soil water.

The results of the water-balance computations for the four basins are shown in Table III-21. The runoff figures for Good Spring and Wilson Creeks are computed for the existing gage sites. The runoff figures for Taylor and Streeter Creeks are computed for the basins' mouths. The runoff figures for Taylor and Streeter Creeks may be underestimated because ground water recharge occurring in the Wilson and Good Spring Basins may appear as discharge in the Taylor and Streeter Basins, respectively. This possibility is not considered in the water-balance procedure for Taylor and Streeter Creeks because the procedure treats the basin as a closed system.

Table III-21
Drainage basin areas and annual water-balance estimates

Basin	Area (square miles)	Precipitation (inches)	Computed evapotranspiration (inches)	Estimated runoff	
				Inches	Acre-feet
Good Spring Creek	39.45	22.52	21.91	0.61	1,270
Wilson Creek	26.98	22.44	21.42	1.02	1,480
Taylor Creek	7.14	21.50	21.17	.33	125
Streeter Creek	2.12	21.55	21.16	.39	45

As with all water-balance computations for areas of low water yield, the probable error in most of the variables entering the water balance may be as large or larger than the predicted runoff values. This is mentioned not to discredit the results but to remind the reader that these figures are initial estimates to be revised as additional data become available. The computed runoff figures in Table III-21 appear to be reasonable initial estimates and the procedure used to compute them has worked well in a hydrologically similar basin (Wymore, 1974). Additional climatic and hydrologic data from the basins in question, however, will surely improve these estimates. Data are being collected to improve these estimates as there is a continuing need to improve the reliability of water-balance estimates.

The lack of sufficient runoff data also necessitates the use of empirical techniques to determine peak flows. An empirical technique called the index-flood method is presented by Patterson and Somers (1966) for the Colorado River Basin. The index-flood method estimates the magnitude and frequency of floods for any recurrence interval from 1.1 to 50 years, using basin characteristics of drainage area and mean altitude. Using flood-frequency analyses of 342 gaging-station records and the relationship among the mean annual flood, drainage area, and mean altitude, the

Colorado River Basin was delineated into 23 hydrologic areas. The Colorado River Basin was also divided into six homogeneous flood-frequency regions (A to F) on the basis of the slopes of the individual frequency curves. This resulted in the definition of six composite frequency curves from which the ratios of mean annual floods to floods having recurrence intervals of 1.1 to 50 years can be derived. The basins in question fall into hydrologic area 3 and flood-frequency region A. Peak flows in region A are typically snowmelt runoff peaks.

The small basin areas and mean altitudes of Wilson, Taylor, Streeter, and Good Spring Creeks cause them to fall outside the range of available data for hydrologic area 3. Estimates of the mean annual flood for Wilson and Good Spring Creeks, however, were extrapolated from the existing data. The estimated mean annual flood for Wilson Creek is 160 c.f.s. (4.5 m^3/s) and for Good Spring Creek is 210 c.f.s. (5.9 m^3/s). Using the composite frequency curve for region A and mean annual flood estimates above, the estimated peak discharge for the flood with a recurrence interval of 50 years is 300 c.f.s. (8.5 m^3/s) for Wilson Creek and 400 c.f.s. (11.3 m^3/s) for Good Spring Creek. Patterson and Somers (1966) stated that the flood-frequency ratios can be used with confidence only up to the 50-year recurrence interval. Extending the relationship to obtain an estimate of the 100-year flood for Wilson and Good Spring Creeks, however, gives peak discharges of 340 and 440 c.f.s. (9.6 m^3/s and 12.5 m^3/s), respectively.

Given the available climatic, topographic, vegetative, and soils data, the peak flow estimates obtained from the index-flood method appear somewhat high. This probably results from the extrapolation beyond the range of available peak flow data. Consequently, the estimates obtained from the index-flood method must be considered initial estimates, to be revised as more data become available.

The smaller basin area and lower mean altitude of Taylor and Streeter Creeks will probably cause their peak flows to result from high intensity rainfall rather than from snowmelt. Peak flows for these two basins were computed using the triangular unit-hydrograph procedure of the Soil Conservation Service (1971). The design storm used in this procedure was the 1-hour rainfall with a return period of 100 years. For this region the estimated 100-year, 1-hour rainfall is 1.5 inches (38.1 millimeters) (Hershfield, 1961). The resulting peak flow from this storm is estimated to be 100 c.f.s. (2.8 m^3/s) for Streeter Creek and 120 c.f.s. (3.4 m^3/s) for Taylor Creek. For comparative purposes the same storm was applied to Wilson and Good Spring Creeks. Using the triangular unit-hydrograph procedure, the resulting peak flows are about 190 c.f.s. (5.4 m^3/s) for Wilson Creek and about 270 c.f.s. (7.6 m^3/s) for Good Spring Creek.

The results of both the index-flood method and the triangular unit-hydrograph procedure are for natural basin and channel conditions.

Existing check dams and other runoff control structures on the basins will alter peak flows from those expected in a natural channel. The effects of these structures are not readily entered into either estimation procedure and therefore were not considered.

Quality

Analyses of water from sites on Taylor, Wilson, Streeter, and Good Spring Creeks, made at the U.S. Geological Survey's Central Laboratory in Salt Lake City, Utah, indicate almost equal proportions of calcium, magnesium, bicarbonate, and sulfate when expressed in milliequivalents per liter. (See Appendix D.) At Streeter Creek, and especially at Wilson Creek, sodium and chloride are also present in significant concentrations. The most abundant trace metals in surface waters are copper, iron, lead, and zinc. Arsenic, cadmium, molybdenum, nickel, and selenium are present in smaller amounts. In the nine samples analyzed, dissolved-solids concentration ranged from about 500 to 1,100 milligrams per liter.

A reconnaissance of an area including the towns of Steamboat Springs, Maybelle, Hayden, Craig, Hamilton, Pagoda, and Meeker was made in August 1974. Specific-conductance measurements were made at streams and springs to determine the normal dissolved-solids concentration of waters discharged through springs and ground water inflow from the Williams Fork, Iles, and Mancos Formations. A conductance range from about 600 to 2,400 micromhos per centimeter at 25° C. was observed in streams draining these formations, with the most common range from 900 to 1,200 micromhos. Analyses made in this study show that specific conductance can be converted to the approximate dissolved-solids content in milligrams per liter by taking 60 percent of the conductance value. Conductance values of about 600 micromhos per centimeter were measured at springs and near the headwaters of Taylor Creek on the Taylor Creek study site.

Streams originating at high altitudes, such as the Yampa, Williams Fork, and White Rivers, have low conductances from 200 to 450 micromhos even where they flow across the Williams Fork, Iles, and Mancos Formations. The low conductance of surface water originating at high altitudes seems to be characteristic of Colorado streams. Precipitation is greater at higher altitudes; there is often very little porous and permeable rock to delay ground water movement to the streams, and concentration of chemicals by evapotranspiration is minor. The result is stream water containing only small amounts of dissolved chemical constituents. Apparently the tributary flow of mineralized waters from the Williams Fork, Iles, and Mancos Formations is too small to cause substantial degradation of the main streams.

Downstream Dissolved-Solids Variations

Dissolved solids increase downstream on all streams due to inflow of higher salinity ground water. Taylor Creek analyses do not show this because the control site was sampled after a very heavy thunderstorm.

Seasonal Chemical Variations

Waters in the perennial streams in the area have variations in dissolved solids and individual chemical constituents at different times in the year.

	Dominant anions	Dominant cations
June	$HCO_3 > SO_4$	$Mg > Ca$
August	$SO_4 > HCO_3$	$Mg >> Ca$

Data suggest that there are at least two distinct lithologic sources (shallow sources and deeper sources) for the chemical constituents found in streams at different seasons.

Effects from shallow sources, soils, and weathered rocks are most noticeable during spring due to snowmelt and following storms. The shallow zone(s) at site A-3 seems to be responsible for concentration of several metals (copper, iron, lead, and manganese) being higher in June than in August. Such a pattern is unusual since the great dilution due to spring runoff would normally lower metal concentrations. It appears that dissolution progresses during low-flow periods in these shallow source rocks but that insufficient water is available to flush the dissolved constituents into the surface waters.

From June to August the concentration of all major ions is increased and many metal concentrations are decreased. Probably such base flow is from deeper aquifers that are not weathered. At both Wilson and Good Spring Creeks, the dominant anion in June is bicarbonate, but in August it is sulfate. Along with sulfate, magnesium is greatly increased. Magnesium (expressed in milliequivalents per liter) is greater than calcium at many sites, which is unusual for surface waters. A source of high magnesium evaporites would be consistent with the high sulfate present. High magnesium waters could also have several other plausible explanations: (1) since coals are significant aquifers, they could be contributing the "unusual" amounts of magnesium, (2) calcium could be precipitating in preference to magnesium which would result in a relative magnesium enrichment (most magnesium compounds are more soluble than similar calcium compounds, hence would stay in solution), and (3) magnesium enrichment could result from cation exchange of calcium for sodium. This process seems quite possible on Wilson Creek where sodium is one of the major cations.

Much of the flow of Streeter Creek is from rock that is lower stratigraphically than the sources for either Taylor or Wilson Creeks. This drainage (see site A 6-a) also has exceptionally high magnesium and sodium, further evidence for a deeper source for base flow.

Trace Elements

One would expect trace metal concentrations to be lower than they are because the pH is often greater than 8. (See analyses for site A-3, June pH 7.8.) It is possible that dissolved organic compounds, either humates from soils or other compounds from the coals and shales, have complexed with some metals, thereby increasing the mobility of the metallic ions and the concentration of "dissolved ions" in the waters sampled. Oxidation of pyrite may also cause dissolution of metals from rocks.

Stream Biota

At this time the data to analyze stream biota are insufficient. Wentz, in Colorado Water Conservation Board Circular 21, reports the presence of diatoms, blackflies, mayflies, caddisflies, snails, beetles (adult), and amphipods at site A-1 (May 17, 1972).

Further Research Needed

1. Continue to inventory aquatic macroinvertebrate communities at all sites at least quarterly because they are good indicators of water quality.

2. Make relatively complete chemical analyses of water from springs in areas to be mined. Several of these analyses should be spectrographic analyses to provide a complete concept of chemical composition.

Subsurface waters

Geology of the Coal-Bearing Formations

Cores from 27 test holes drilled by W. R. Grace and Company were examined at the company core library using a binocular microscope with low magnification. These are continuous, diamond-cut cores and range in length from a few hundred feet to about 2,200 feet (470 meters). In most cases, the upper 20 feet (6.1 meters) of each hole was not cored, but a few holes were cored from land surface so that the characteristics of weathered formations were observed.

Four basic rock types are present in the Williams Fork and Iles Formations. In order of abundance, they are sandstone, shale or mudstone, siltstone, and coal. In addition, bentonitic clays are present as thin zones a few inches to a few feet thick.

Sandstone beds in this area are uniform in their characteristics although they vary in thickness from a few feet to massive beds well over 70 feet (21 meters). They are light colored, from white to gray. Grain size ranges from very fine to medium, with very fine size predominating. The sand grains are usually cemented with calcium carbonate or a matrix of very light-colored, probably bentonitic, clays. Inclusions in the sandstone beds are carbonized plant fragments, small amounts of pyrite, and occasional pebbles of sandstone, shale, silt, and chert. A rock type that is a mixture of very fine sand and silt is abundant, and this material usually displays contorted gray to dark gray shale laminae exhibiting drag folds and other flow structures. Visible porosity is rare and the sandstone beds seldom exhibit good water-bearing characteristics. Fractures probably are the principal avenues for fluid movement and the most important voids for fluid storage in sandstones.

Sandstones found within about 30 feet (10 meters) of the surface usually are partly decomposed, iron stained, and highly fractured. Such decomposed rocks usually are not seen below the first thick shale zone but occasionally persist to depths of as much as 100 feet (30 meters).

Shale beds at the Taylor Creek site are usually gray to dark gray with occasional black coaly zones. They grade from pure shale to bentonitic, silty, or sandy shale. A few massive, dark gray beds with marine shell fossils are present in the section. The shale beds are often thin but some are as much as 30 feet (9.1 meters) thick. Partings with a slickensided appearance are common, especially in bentonitic zones in which all of the shale has these partings. Most of the low angle slickensides are thought to be flow structures associated with compaction but those at 30 to 50 degrees from the horizontal appear to be small faults. Tan chert nodules are common in the shales.

Shales in the weathered zone are commonly soft and finely laminated and have many fractures. The unweathered shales are firm to hard and usually break conchoidally. Coaly zones are the only deep shales to commonly show fissile characteristics.

Siltstones in this area are of two general types: (1) light colored, siltstone-sandstone mixtures with contorted shale laminations previously mentioned and (2) darker shaley siltstones. Usually the light siltstones are thicker, up to 30 feet (9.1 meters) whereas the shaley siltstones are seldom more than 10 feet (3 meters) in thickness.

Siltstones appear to weather less readily than sandstones and shales but are commonly fractured and iron stained near the land surface.

Coal occurs in seams as thick as 30 feet (9.1 meters) and also in seams a few inches to a few feet thick. The major seams were given alphabetical names from A to K by early workers in the areas. Subsequent geologic investigations resulted in the discovery of seams X and Y on the top

of several ridges in the area. Apparently these seams had little surface expression and were not observed by early surface workers. It is not known at this time whether the coal members are truly correlative, but mining has shown that some zones are continuous for as far as one-half mile (0.8 km). Most coal seams contain pure coal with shaly coals scarce except at gradational boundaries. The coal exhibits vertical fractures; often the fracture surfaces have a thin coating of minute pyrite crystals.

In test holes and at seeps, water is most commonly found associated with coal beds, apparently because coal has the most fractures. At surface seeps, the flowing water often removes soil materials leaving part of the coal bed exposed.

Thermally Altered Beds

The thermally altered deposits have a great variety of nicknames--"red dog" and "clinker beds" being quite common. Thermally altered beds are common in the western coal-producing areas. They are caused by fires that started in surface outcrops of the coal beds. Several fires are still burning underground in the Axial area, including one at the Colowyo Mine.

The effects of underground fires on adjacent beds are twofold. The first effect is alteration of rocks and rock minerals. Iron-bearing rocks and minerals change from black and gray to red as the iron is oxidized; clays are also altered and often decomposed. The heat, fumes, and hot water vapor make the alteration a chemical as well as a physical process. The second effect is collapse of overlying rock into the voids created by the burning coal and development of a secondary fracture system. This fracturing is possibly increased because of loss of strength due to decomposition of the rock.

Thermally altered beds have been found in some core holes as much as 300 feet (91 meters) below the surface. Because of extensive fracturing and decomposition these beds are highly permeable and porous, thus receptive to recharge from precipitation. They also have the best reservoir characteristics of any rocks in the area. It is unlikely that any of these beds occur below present water tables but, if so, they have good potential as a source of ground water.

Aquifer Characteristics

In summary, few of the unweathered rock types in the Williams Fork and Iles Formations appear to have porosity and permeability desirable in a productive aquifer. The sandstones have only small zones of visible interstitial porosity and sparse fractures. The shales and siltstones have only sparse fracture porosity. The coal seams that appear to be the principal water-bearing zones in the section have well developed fracture porosity.

Most of the weathered and decomposed rocks, including the thermally altered beds, have interstitial porosity resulting from decomposition as well as rather extensive fracture porosity. Weathered rocks resting on unweathered rocks of low permeability account for the many perched water zones found at shallow depths in this area.

Depth-to-Water

Seventeen observation wells have been established to measure fluctuations in water levels at the Grace site. Depth-to-water ranges from less than 20 feet (6 meters) to more than 500 feet (152 meters) at these wells. (See Water Level Measurement Table in Appendix D.) Three 25-foot (7.6 meters) holes were augered by the Bureau of Reclamation in the flood plains of Good Spring, Taylor, and Wilson Creeks. A 25-foot (7.6 meters) auger hole was completed near the crest of a ridge on the east side of the Taylor Creek site. Two core test holes drilled by the Bureau of Reclamation about 200 feet (61 meters) deep were completed as observation wells and seven core tests drilled by W. R. Grace and Company were cased for observation wells. In addition to these wells, the U.S. Geological Survey contracted to have four test holes drilled in the valleys of Streeter and Taylor Creeks (see well logs in Appendix D), and these holes were drilled to depths of 60 to 100 feet (18 to 30 meters). None of these wells have a yield of more than 5 gallons per minute (0.3 l/s). Pairs of wells were drilled at three sites and cased with 6-inch (150 millimeters) diameter pipe to allow accurate aquifer testing.

Of the four augered holes, the water level in #3 on Taylor Creek declined below the bottom of the hole in the early fall when a tributary stopped flowing, and the others show small water level fluctuations. The rest of the holes in bedrock show normal water fluctuations. Some bedrock wells in the stream valleys are under low artesian head.

In four of the W. R. Grace and Company core holes, #27, #33, #35, and #45, water at depths of less than 100 feet (30 meters) is issuing out of perched water zones and flowing down the well bores. In Grace #33 and #35 there was no accumulation of water at depths of 280 feet (85 meters) and 500 feet (150 meters), respectively. In Grace #45 there is water at a lower depth which may not be a true static water level, and similarly in Grace #27 water is moving in considerable quantities down hole from a depth of about 80 feet (24 meters) and measurements are stable only near the plug-back depth of 295 feet (90 meters). This and other well data indicate that ground water has been drained from the dissected upper part of the Williams Fork Formation.

At the Taylor Creek site much ground water is perched on the highest impermeable bed and is commonly found at depths of less than 30 feet (9.1 meters). Deeper beds are often unsaturated, although some confined water has been found in the stream valleys at depths of less than 100

feet (30 meters). It is unlikely that substantial quantities of ground water will be found at depth at the Taylor Creek site because the Iles and Williams Fork rocks are generally of low porosity. Also, the beds terminate a few miles north at the edge of the Axial anticline providing a small recharge area in that direction. The Collum syncline, an east-west fold at the north side of the site, is a feature with a small exposed section so there is little recharge to deeper beds from that direction. Regional dip from Axial to Meeker is to the south, so much of the ground water recharged south of the Collum syncline moves away from the Taylor Creek site. The fact that the Colowyo Mine workings were dry, although at a lower elevation than Streeter and Good Springs Creeks, also indicates the generally unfavorable aquifer development in the vicinity of the Taylor Creek site.

Sediment yield

Much of the information presented in this section on sediment yields applies to premining conditions on the Taylor Creek study site. If the site is mined and reclaimed, this information will be useful in evaluating the efficiency of reclamation with respect to erosion and sediment yields. The information should also be useful to those who will design the reconstructed topography if the study site is mined. The sediment yield values presented for the site were derived using a qualitative rating method and have been judged to be reasonably accurate, but they have not been verified by actual measurements.

The method used to obtain the annual source-area sediment yield estimates was the (PSIAC) Pacific Southwest Interagency Committee (1968) method which entails the rating of ten factors: surface geology, soils, climate, runoff, topography, ground cover, land use, upland erosion, channel erosion, and sediment transport. While the method was developed to make broad sediment yield classifications for large areas, such as river subbasins, Shown (1970) found that the method provides reasonable estimates for small drainage basins such as those within the sediment yield mapping units shown on Figure III-9.

Sediment yield estimates were actually made on seven relatively homogeneous, small watershed areas throughout the study site. Aerial photographs (1:12,000 scale) were then used to extend the estimates to the whole study area. Systematic interpretation of the photographs included consideration of (1) vegetation type, (2) density of the vegetation, (3) landform type, (4) steepness and length of slopes, and (5) drainage density. Categories 2, 4, and 5 were rated on a relative basis within the mapped area on a scale ranging from 0 to 3, which corresponds to none,

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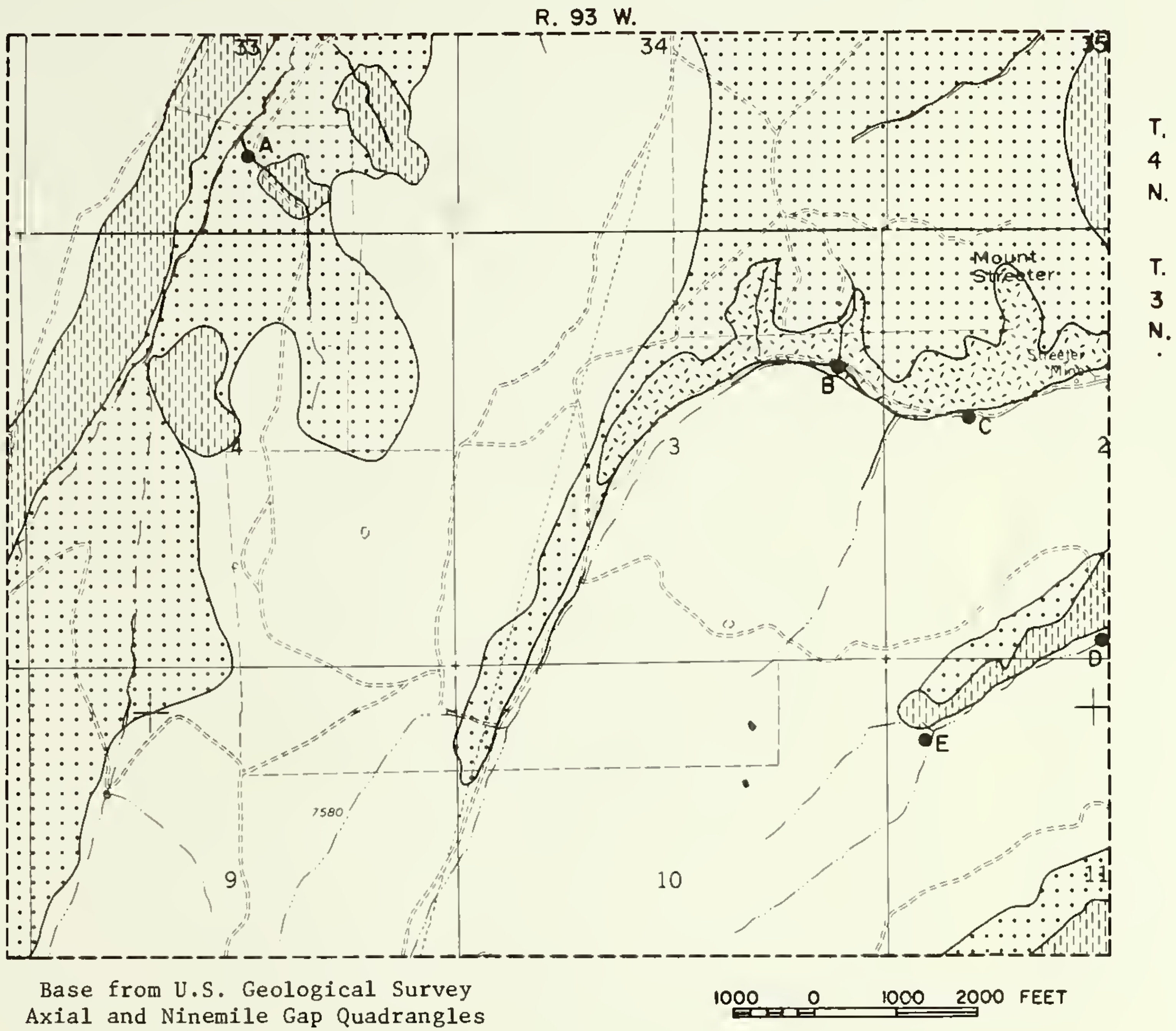
Note: The following sections are in preparation: (1) direction and velocity of flow, (2) results of pump testing, (3) chemical quality, and (4) potentiometric surface map.


R. 93 W.
33
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T. 4 N.
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Base from U.S. Geological Survey
Axial and Ninemile Gap Quadrangles

ANNUAL SOURCE-AREA SEDIMENT YIELDS AND CHANNEL CONDITIONS
FOR THE TAYLOR CREEK STUDY SITE, COLORADO

EXPLANATION

Annual source-area sediment yields (acre-ft/mi^2)		Topography	Slope gradients Range (percent)	Slope gradients Mean (percent)	Drainage density (mi/mi^2)
☐	0 - .2	rolling plateau	8-32	11	2.2
⁙	.2- .4	rolling plateau	12-44	26	5.0
▥	.8-1.2	hillslope	25-44	37	3.1
░	1.2-1.6	hillslope	24-58	46	15.6

● B Locations of the outlets of drainage basins for which sediment yield estimates were made

∼ Gullied channels

Figure III-9

[illegible]

low, medium, and high. These relative values were quantified later using U.S. Geological Survey 1:24,000-scale topographic maps for slope measurements and the aerial photographs for channel mapping and drainage density measurements. The quantified values are shown in the explanation table of Figure III-9. The drainage density values shown represent the miles of channel per square mile of area considering only channels of third order or larger as discerned on the 1:12,000-scale aerial photographs.

The source-area sediment yields, while low for much of the site, are fairly well related to the mean slope of the mapping units shown on Figure III-9 as is indicated by the data in the explanation table of Figure III-9. Parts of the low sediment-yielding areas (0-0.2 and 0.2-0.4 acre-foot per square mile) have moderately steep slopes, but the generally excellent vegetation cover on them prevents erosion. The higher sediment-yielding areas on the site are generally steep-sloped areas oriented southerly or easterly and have significantly less vegetative cover than the lower sediment-yielding areas.

The basin sediment yields shown in Table III-22 for several drainage basins on the site were computed by multiplying the area-weighted, source-area sediment yield for each basin by a sediment delivery factor based on gullied channel density (Table III-22), on field observations and photo interpretation of the channel conditions. This was a modification of a rating scheme for obtaining sediment delivery factors that were developed by Frickel, Shown, and Patton (1975). Their scheme considers the effects of various conditions such as (1) channel width and gradient, (2) whether the channel is gullied or just a broad, grassy drainageway, (3) the size of the bed material and vegetative cover on the bed, (4) intermittent gullies in the channel system, and (5) evidence of deposition in the channels and the occurrence of alluvial fans and deposition on bottom lands where flows spread either naturally or because of man-made impoundments or diversions of water.

Table III-22
Sediment yields for selected drainage basins on the Taylor Creek study site

Basin[1]	Drainage area (square miles)	Mean watershed slope (percent)	Gullied channel density (miles/ square mile)	Mean source-area sediment (acre-feet/ square mile)	Sediment delivery factor	Basin sediment yield (acre-feet/ square mile)
A	0.50	16	0.3	0.21	0.3	0.06
B	.08	20	2.6	.46	.75	.35
C	2.18	19	1.2	.21	.5	.10
D	.50	22		.15	.4	.06
E	.19	9		.10	.1	.01

[1] The locations of the arbitrarily chosen outlets of the basins are shown on Figure III-9.

Without reference to a mining plan for an area, it is difficult to assess the effects that surface mining will have on the sediment yield of that area. Nonetheless, some PSIAC estimates of sediment yields from overburden areas were made under assumed conditions for surface materials, slope gradients and orientations, and cover as shown in Table III-23. Some guidelines for surface mine reclamation prepared by the Soil Conservation Service in Montana (U.S. Department of Agriculture, 1971) were referred to in making assumptions.

Table III-23
PSIAC estimates of annual source-area sediment yields from presumed overburden areas before, during, and after reclamation on the Taylor Creek study site

	Slope gradient and orientation (percent)	Bare soil (percent)	Sediment yield (acre-feet/ square mile)
Ungraded overburden banks	80-100	80 (rock, 20)	0.75-1.25
Graded overburden[1]	0- 5	80 (rock, 20)	.40- .60
	15- 25	80 (rock, 20)	.75-1.25
Overburden DURING the reclamation period[2][3]	0- 5	25-35	.25
	15- 25 N.	20-25	.35
	15- 25 S.	35-40	.55
Overburden AFTER the reclamation period	0- 5	5-10	.2
	15- 25 N.	0- 5	.2
	15- 25 S.	20-25	.4

[1] Consists of sand, silt, and clay, and some sandstone fragments.

[2] The following assumptions were made regarding reclamation techniques: (1) the overburden would be covered with 1 to 2 feet of clay loam soil, (2) the area then would be close-spaced, contour furrowed, and seeded with adapted perennial grasses and shrubs, and (3) the area would be protected from grazing during this period.

[3] Cover and sediment yield values are averages for the period.

As noted in Table III-23, it was assumed that there would be enough soil on the site to top the replaced overburden and thus effect a faster establishment of vegetation. The soil, however, is fine textured and probably will be compacted after it has been spread. Close-spaced contour furrowing (Branson, Miller, and McQueen, 1966) or gouger pitting (Sindelar, Hodder, and Majerus, 1973) would loosen the soil, reduce runoff and erosion, and increase soil moisture. If the overburden itself, without a soil topping, is used for growth media, compaction may be a lesser problem owing to the sand and rock in the overburden. Nonetheless, the overburden will be more erodible because it would be less cohesive, and it would be desirable to prevent any overland flow and erosion by mechanical treatment, particularly on the sloping areas.

The large estimates for sediment yields from ungraded and graded but barren overburden areas, shown in Table III-23, emphasize the necessity for establishing vegetative cover on them as soon as possible if the study area is mined. Sediment yields from the overburden areas during the reclamation period, when the permanent vegetation and soil structure is becoming established, will be greater than the present rates from those areas shown on Figure III-9 yielding less than 0.2 acre-foot per square mile. The sediment yield estimates in Table III-23 indicate that sediment yield from the overburden areas during reclamation and afterward would be minimized if sloping areas oriented to the north were maximized. Orientation of slopes toward the east would have a similar effect. Sediment yields would also be minimized if the reconstructed terrain includes rather wide valleys. Then, if the valleys trench, hillslopes would be intercepted only at places where the stream meanders to the valley sides. Thus, hillslope areas from which material might slough, creep, or slump into the channels would be minimized.

Potential supply for reclamation and rehabilitation

Three pairs of shallow wells on Streeter Creek are to be tested for yield and water chemistry. The results will be published in the next annual U.S. Geological Survey report.

IV

LEGAL REQUIREMENTS ON MINE LAND RECLAMATION

State Regulations

Reclamation of surface-mined coal lands in Colorado is governed by the "Colorado Open Mining Land Reclamation Act," Chapter 92, Article 13, Colorado Revised Statutes, as amended, September 15, 1973.

A permit, bond, and filing fee are required from all surface-mine operators. The bond is set at an amount to ensure the completion of the reclamation plan.

The reclamation requirements include grading of peaks and ridges to a rolling topography, burying acid-forming materials, constructing water impoundments in final cuts, constructing fire lanes and access roads in forest areas, and revegetating subject to the approval of the Colorado Department of Natural Resources.

The authority for enforcement of this law is with the Executive Director of the Department of Natural Resources.

The Water Pollution Control Act makes pollution of waters of the State unlawful. Refer to the "Water Pollution Control Act, Chapter 66, Article 28, Colorado Revised Statutes as Amended."

The Water Pollution Control Commission is empowered for the water quality standards of the State. The fine for violation is from $50 to $2,500 for each day of violation. The commission has authority to institute civil action in any court of competent jurisdiction to stop mining operations until compliance with the pollution act has been met. The commission issued guidelines for control of water pollution from mine drainage on November 10, 1970, along with recommended measures to prevent entry of water into mine workings, to minimize formation and discharge of polluted drainage that does not enter mines, for disposal of refuse so as to minimize polluted discharge, for treatment of drainage prior to discharge of acidic or toxic drainage after closing operations, and to encourage reuse of drainage for other purposes whenever possible.

Local (County) Regulations

There are county zoning regulations that will affect the coal stripmining operations, namely in the area of sanitation practices, disposal of sewage, and the use of culinary water. Building and electrical codes

will also have to be followed. The extent of all local regulations can be obtained from the Moffat County Court House, Craig, Colo.

The local regulations are not intended to be as explicit regarding surface mining and reclamation as are the State laws discussed previously in this section. Successful reclamation and revegetation of surface-mined lands at the Taylor Creek site will depend upon an environmental awareness and an intensive and coordinated effort by the industry to comply with Federal, State, and local regulations.

V

EFFECTS OF MINING ON AREA HYDROLOGY

Potential Effects on Surface and Subsurface Water Supplies

Surface mining

Surface mining excavations will cause draining of small quantities of water from perched aquifers to lower levels in the excavations where it will usually infiltrate rapidly. It is anticipated that this diverted ground water will then move down-dip in any porous or fractured rock and that there will be little net loss to the system. Draining water from near the land surface may cause some springs and seeps to dry up. New springs and seeps may develop at the base of spoil piles because of shallow water being diverted to this level and because new spoil materials have great recharge from precipitation. Vegetation patterns will shift with any change of shallow water available to plants. The concentration of dissolved chemicals will increase when water moves through spoil materials.

Underground mining

If substantial amounts of ground water are intercepted in deep underground operations, it will be necessary to dispose of water by pumping it to the surface. This probably will not create serious problems because of the low content of dissolved chemicals in ground water of this area.

Underground operations at the site have not encountered enough ground water to operate mining equipment year round, so it seems there is not much likelihood of large water disposal problems in future mining.

Drainage and Pollution Hazards That Could Occur

Surface mining

Sediment discharge to Taylor and Good Spring Creeks will be increased without some means to control the sediment from the overburden areas during mining and reclamation. This could be accomplished by reservoirs immediately downstream from the mined area and from which the water would be discharged in nonerosive quantities. The reservoirs may need to be cleaned out periodically to maintain storage capacity and it may be desirable, for a number of reasons, to destroy the dam and spread the dam material and sediment at the end of the rehabilitation period.

Increased sediment yields may occur from the area downstream from a mine if water from the mine or a reservoir is discharged more or less continuously into channels that were formerly dry most of the time. These discharges would probably be small and thus nonerosive; however, they would saturate the bed and banks of the channels. Then during a natural flood event, severe erosion could occur, particularly in presently ungullied channels, because saturated alluvium is much more erodible than dry alluvium.

Underground mining

Underground mining has the distinct advantage of almost being a silt-free operation. The likelihood of more ground water at depth makes this type of mining more likely to cause chemical weathering, but the surface area of rock material is increased only slightly by tunneling and by fracturing associated with collapse of abandoned workings, so chemical weathering should be relatively unimportant.

Also relating to the measured water-level data is the behavior of Streeter Creek, which about 2 years ago ceased flowing in the burned-out area above the Colowyo Mine workings and is now seeping underground. Historically, the Colowyo Mine ran out of seepage water about August of most years and water had to be brought in to operate underground mining equipment.

As is seen in the case of the Colowyo Mine, collapse or induced fracturing can divert surface flow underground or can also change ground water movement. In almost all cases, such effects will result in local disruption of water movements and probably will not create serious pollution problems, although such diversions can create a mining problem.

It could be added that, although some underground mining has taken place throughout the area for many years, our reconnaissance indicates there are few known instances of high chemical concentration in the streams.

It may be possible to spot check a few surface mines in the Hayden area with similar geology to observe the chemistry of the water associated with the disturbed rock.

The natural dissolved-solids content of ground water and surface water does not vary greatly, as shown by comparing the conductance of springs and seeps with that of the nearest stream. Usually, the streams have a higher conductance of 100 to 200 micromhos per centimeter. None of the rock materials in the coal-bearing formations contains large amounts of minerals that would be particularly susceptible to chemical weathering. The visible pyrite content of the coals is substantially less than 1 percent, but it is possible that the production of acid from the oxidation of pyrite may be important in the dissolution of metals from the coals and shales.

Even though the surface area of rock materials will be increased at least one order of magnitude by strip mining, the amount of ground water available for solution of minerals is the limiting factor. Since there is very little ground water in the upper 150 feet (46 meters) of rocks that will be strip mined, important increases in chemical content of ground and surface water in the area are not anticipated although increases may occur locally.

Copper and zinc are the most abundant trace elements found in surface water samples, but many trace elements are present in minute quantities. Periodic checks of water should be made to see that concentrations of a single metal or a combination of metals does not develop that could cause a local health or environmental hazard.

Conclusions

The reclamation effort will be to restore or upgrade the existing characteristics of the land and vegetative cover on the disturbed areas. Detailed studies of the soil mantle, overburden, climate, and other environmental conditions indicate that the overburden or disturbed material and other conditions are satisfactory and that reclamation of mined areas can be accomplished by following a planned program.

Two major alternatives of reclamation with variations are proposed. The first method makes no provisions for stockpiling or placement of available topsoil on disturbed areas, while the second method requires stockpiling of the strippable topsoil and placement on disturbed areas. Variations of these methods include the different types of disturbed area shaping by mechanical manipulation and seedbed preparation. This shaping will likely be a requirement beyond just striking off or rounding off ridge tops and will involve restoration of the original contour of the area.

During this study, characterization of the geologic overburden material indicated little if any adverse effects would be expected during the restoration and reclamation of the disturbed areas. Chemical and physical data presented in the report do not indicate excessive concentrations of toxic minerals or elements including salts in the sandstone and mudstone materials. Chemical data from the shale layers show occasional high reading indicating excessive concentrations of soluble salts that may affect reclamation, but the layers are few and isolated and with mixing of the overburden material during excavation they should not be a problem.

Results of numerous studies show that the stripping, stockpiling, and replacement of topsoil on disturbed overburden material will enhance and increase the success for reestablishment of vegetation. This would be true at the Taylor Creek site also, but indications are that it may not be

a requirement. Soil analysis and survey work indicate that only 46 percent of the area has sufficient soil depth to allow for stripping and stockpiling of topsoil. Evidence from the results of the Seneca Mine revegetation program indicates that direct sedding of contoured and shaped disturbed areas would also be a feasible method of reclamation at the Taylor Creek site.

View of reseeded cast overburden at the Seneca Mine site near Hayden, Colo.

Variations to the major alternatives could include either chiseling, gouging, pitting, contour furrowing, dozer basins, and other practices to reduce water runoff, erosion, and aid in seedbed preparations.

Another variation of the major methods of reclamation would be the placement of undesirable overburden layers at greater depths and an allowance for placement of the finer-textured material near the surface. The coarser fragmented rocks should be buried wherever possible. Some of the shales, mudstones, and sandstones when exposed to natural weathering processes will break down in time to form a suitable material for plant media. The large rock fragments, more resistent to weathering, will not adversely affect the plant media if they are dispersed over a wide area.

Additional cultural practices used in establishing a vegetative cover such as fertilizing, mulching, irrigating, transplanting, and other methods of seeding can be utilized with each major alternative.

An area may be selected and considered for future study for the use of plant species adaptable to the site. Depending on the future land use, however, a seeding mixture of either all-native species or native and introduced species would be the most logical procedure to follow.

Seneca Mine site near Hayden, Colo. View of reseeded area on cast overburden in lower portion of picture, with native vegetation in the upper portion.

Natural recovery, although not considered as an alternative, is a possibility. It is a slow process at best in semiarid regions. Natural recovery of disturbed areas usually progresses through three stages of succession as follows: (1) annual forbs, (2) grass forbs, and (3) shrub grass. For the Taylor Creek site the time requirement for natural recovery has not been determined but should be considered as an alternative to reclamation.

Direct seeding of the reshaped mined areas by broadcasting is recommended on areas where seedbed preparation is impossible and where topsoiling is not a requirement of the reclamation program.

Essentially, the requirements for removal, stockpiling, and replacement of topsoil consist of a series of earth-moving operations. The surface soils should be deposited in different stockpiles than that of the

subsurface and protected from erosion. These stockpiles should be located where they will be accessible for resurfacing over the mined area as needed.

Effective shaping of the disturbed areas to a preconceived design is essential to these lands so that they blend with adjacent topography of undisturbed lands and minimize drainage problems. In the study area, it is recommended that the disturbed material be placed back in the pit and graded to a rolling-type topography with slopes not steeper than 4:1, and wherever possible they should preferably be graded to a 5:1 slope or less. Drainageways should be provided in the topographic design of the areas and grades should be flat enough to prevent gullying and excessive channel erosion. Final grading should insure that no flat areas are created which will pond water unless temporary ponding is a part of the entire erosion control program for the area. Recommendations for revegetation are:

1. Fall seeding, preferably before October 15, appears to produce the best results in this area. Grasses and legumes should be planted as soon as possible following the seedbed preparation.

2. Avoid monocultures in grass stand selection. Choose a good mix of adapted species which are drought resistent and have good sod-forming characteristics.

3. When a range mixture is used, increase the recommended rates by at least 50 percent.

4. Drilling should be given first consideration for seed application.

5. Where trees are included in the revegetation process, give first consideration to transplanting mature stock rather than planting seedlings or seed.

Finally, proper post management of the reclaimed areas is essential if reclamation is to be successful, such as fencing to exclude overgrazing and erosion and additional fertilizing when needed to maintain and insure complete establishment of adapted plant species.

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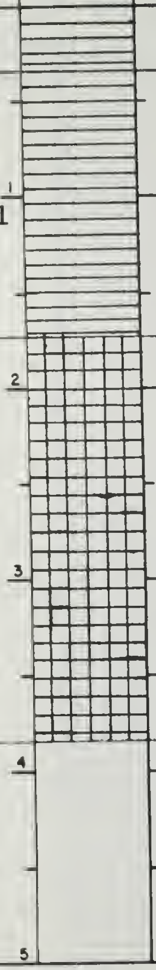
APPENDIX A

CHARACTERIZATION OF SOIL AND OVERBURDEN MATERIAL

This appendix contains the supporting data utilized in the characterization of the soil and overburden material at the Taylor Creek study site. It includes (1) 12 typical soil profile information sheets as prepared by the Bureau of Reclamation, (2) 31 profile logs for the Texoma auger holes, and (3) summary data sheets for laboratory analysis of soil and overburden material.

TYPICAL SOIL PROFILE

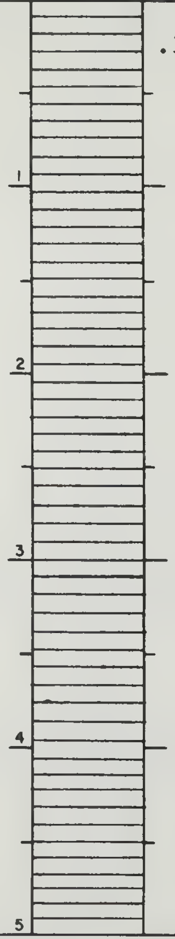
PROJECT Taylor Creek Site AREA Colorado TYPICAL PROFILE NO I

(in)	Log	EC x 10³	Exch. Na. Meq./100gm	Horizon	Soil profile description (Color, texture, structure, consistence, and variations, etc.)
0-3-5		.767	.22	A_1	Very dark grayish brown dry (10yr 3/2), very dark gray moist (10yr 3/1), loam, moderate peds medium size, crumb, soft dry, friable moist, abundant fine to medium random roots, clear wavy boundary.
3.5-21		.489	.22	A_2	Dark brown dry (10yr 3/3), very dark gray moist (10yr 3/1), some brownish yellow fe mottling (10yr 6/8), Loam, strong medium subangular blocky peds, hard dry, firm moist, plentiful fine to medium vertical roots, clear and wavy boundary.
21-46		.319	.23	C	Very dark grayish brown dry (10yr 3/2), grayish brown moist (10yr 5/2), some yellowish brown Fe mottling (10yr 5/4), shale, strong very coarse prismatic peds, very hard dry, firm moist, continuous thick clay films, few medium vertical roots, + lime reaction, abrupt and wavy boundary.
					Note - (C) Horizon, weathered shale, particle size analysis denotes clay loam texture.

REMARKS:

TYPICAL SOIL PROFILE

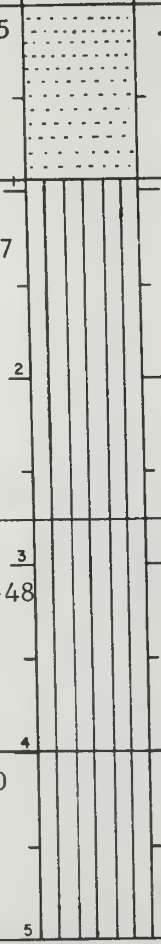
PROJECT Taylor Creek Site AREA Colorado TYPICAL PROFILE NO. II

(in)	Log	EC x 10^3	Exch. Na. Meq./100gm	Hori-zon	Soil profile description (Color, texture, structure, consistence, and variations, etc.)
0-60		.341	.24	A	Dark grayish brown dry (10yr 4/2), very dark brown moist (10yr 2/2). Loam, moderate peds medium size, crumb, soft dry, friable moist, many fine random grass roots with a few medium vertical sage roots, about 5% fragmented sandstone, + lime reaction.

REMARKS:

TYPICAL SOIL PROFILE

PROJECT Taylor Creek Site AREA Colorado TYPICAL PROFILE NO III

(in)	Log	EC x 10^3	Exch. No. Meq./100gm	Horizon	Soil profile description (Color, texture, structure, consistence, and variations, etc.)
0-11.5		.591	.19	A_1	Brown dry (10yr 5/3), dark yellowish brown moist (10yr 3/4), sandy loam, single grain fine crumb, soft dry, firm moist, abundant fine random roots, about 1% sandstone, clear and smooth boundary.
11.5-33.7		.565	.64	B_1	Dark yellowish brown dry (10yr 3/4), dark grayish brown moist (10yr 4/2), slight amount of brownish yellow fe mottling (10yr 6/8), clay, strong prismatic with well defined faces, very hard dry, very firm moist, continuous thick clay films, abundant fine to medium vertical roots, + lime reaction, clear and smooth boundary.
33.7-48		5.10	.91	B_2	Black dry (10yr 2/1), black moist (10yr 2/1), organic clay, weak fine crumb, soft dry, firm moist, plentiful fine and medium vertical roots, + lime reaction, clear and wavy boundary.
48-60		4.52	1.03	B_{22}	Very dark brown dry (10yr 2/2), dary grayish brown moist (10yr 4/2), some fe mottling dark brown (10yr 4/2), clay, moderate fine crumb, hard dry, firm moist, few medium vertical roots, + lime reaction, clear and wavy boundary.

REMARKS:

TYPICAL SOIL PROFILE

PROJECT Taylor Creek Site AREA Colorado TYPICAL PROFILE NO. IV

(in)	Log	EC x 10^3	Exch. Na. Meq./100gm	Hori-zon	Soil profile description (Color, texture, structure, consistence, and variations, etc.)
0-5				A	Dark brown dry (10yr 3/3), dark yellowish brown moist (10yr 4/4), clay, moderate medium prismatic, very hard dry, firm moist, continuous thick clay films, abundant, very fine and vertical roots, + lime reaction, clear and smooth boundary.
5-32		.427	.29	A1	Dark brown dry (10yr 3/3), dark yellowish brown moist (10yr 4/4), clay, strong very coarse prismatic peds, very hard dry, firm moist, continuous thick clay films, few fine and medium vertical roots, clear smooth boundary.
32-36	s i	.345	.32	B_{ca}	Gray dry (10yr 5/1), gray moist (10yr 5/1), silty clay, massive to strong subangular blocky, hard dry, firm moist, very few medium vertical roots, +++ lime reaction, clear and wavy boundary.
36-48	s i	.405	.23	C	Brownish yellow dry (10yr 6/8), brownish yellow moist (10yr 6/8), silty clay loam massive, very hard dry, very firm moist, few medium vertical roots, +++ lime reaction, clear and wavy discountinued boundary.
48-60	Mud-stone	-	-	D	Fragmented mudstone.

REMARKS: Shale below 5'

TYPICAL SOIL PROFILE

PROJECT Taylor Creek Site AREA Colorado TYPICAL PROFILE NO. V

(in)	Log	EC x 10^3	Exch. Na. Meq./100gm	Horizon	Soil profile description (Color, texture, structure, consistence, and variations, etc.)
0-4	▤	.988	.27	A	Yellow dry (10yr 7/6), yellowish brown moist (10yr 5/6), some pale brown mottling (10yr 6/3) loam, weak fine crumb, slightly hard dry, friable moist, abundant very fine and fine random roots, +++ lime reaction, clear and smooth boundary.
4-6	+ + +	.650	.26	C	Yellowish brown dry (10yr 5/6), yellowish brown moist (10yr 5/6), sandstone, fractured, very hard dry, very hard moist, plentiful fine to medium random roots, 100% sandstone, +++ lime reaction, abrupt and smooth boundary.
6-16	▤	.380	.27	C_{ca}	Light gray dry (10yr 7/2), pale brown moist (10yr 6/3), some light gray mottling (2.5yr 7/2), loam, weak medium subangular blocky, slightly hard dry friable moist, plentiful medium vertical roots, +++ lime reaction, clear and wavy boundary
16-34	+ + +	-	-	D	White dry (10yr 8/2), yellowish brown moist (10yr 5/4), sandstone fractured, very hard dry, very hard moist, few medium vertical roots, 100% sandstone, + lime reaction, abrupt top boundary, defused and wavy bottom boundary.
					Note Below 34", shale with thin stratified lenses of sandstone, the (C) horizon, weathered sandstone, particle size analysis denotes loam.

REMARKS: Color of non weathered sandstone is yellow (10yr 7/6)

TYPICAL SOIL PROFILE

PROJECT Taylor Creek Site AREA Colorado TYPICAL PROFILE NO. VI

(in)	Log	EC x 10^3	Exch. Na. Meq./100gm	Horizon	Soil profile description (Color, texture, structure, consistence, and variations, etc.)
0-2		1.60	.27	A	Brown dry (10yr 5/3), dark brown moist (10yr 4/3), clay loam, weak fine crumb soft dry, friable moist, abundant fine and very fine random roots, about 1% fragmented sandstone, defused and wavy boundary.
2-4		1.25	.28	A_3	Brown dry (10yr 5/3), dark brown moist (10yr 4/3), clay, weak fine crumb, soft dry, friable moist, abundant fine and very fine random roots, about 1% fragmented sandstone, ++ lime reaction, top boundary defused and wavy, bottom boundary clear and smooth.
4-28		.369	.48	B_{ca}	Light brownish gray dry (2.5y 6/2), dark grayish brown moist (2.5y 4/2), some fe mottling (7.5yr 5/8), clay, strong medium prismatic peds, very hard dry, firm moist, continuous thick clay films, few medium vertical roots, +++ lime reaction, clear and smooth boundary.
28-60	s i	.492	.78	C_{ca}	Light yellowish brown dry (2.5y 6/4), light olive brown moist (2.5y 5/6), some fe mottling (7.5yr 5/8), silty clay, strong medium angular blocky, very hard dry, firm moist few medium vertical roots, +++ lime reaction, clear to defused and wavy boundary. Note 5'-6' Weathered shale 6 -7 Organic shale 7 -9 Coal 9 -10 Organic shale stopped at 10' due to sandstone

REMARKS: The material from 28"-60" is stratified with weathered shale and mudstone.

TYPICAL SOIL PROFILE

PROJECT Taylor Creek Site AREA Colorado TYPICAL PROFILE NO VII

(in)	Log	EC x 10^3	Exch. Na. Meq./100gm	Hori-zon	Soil profile description (Color, texture, structure, consistence, and variations, etc.)
0-2		1.20	.39	A	Dark gray dry (10yr 4/1), black moist (10yr 2/1), clay loam, weak to moderate fine platy, hard dry, very friable moist, abundant fine and very fine random roots, clear and smooth boundary.
2-11		.662	.29	A_1	Dark grayish brown dry (10yr 4/2), very dark grayish brown moist (10yr 3/2), clay, weak to moderate fine prismatic to subangular blocky, hard dry, friable moist, few thick clay films, abundant fine and very fine random roots, defused and wavy boundary.
11-23		.372	.47	A_{ca}	Dark gray dry (10yr 4/1), light gray moist (10yr 7/1), clay, weak to moderate fine prismatic to subangular blocky, hard dry, firm moist, few thick clay films, abundant fine and medium vertical roots, ++ lime reaction, defused and wavy boundary.
23-29		.400	.44	B	White dry (10yr 8/1), white moist (10yr 8/2), clay, strong fine subangular blocky peds, slightly hard dry, friable moist, abundant fine and medium vertical roots, +++ lime reaction, defused and wavy boundary. (2" thin lenses silica concreations with fe stains)
29-36		.450	.41	C	Very pale brown dry (10yr 7/4), light yellowish brown moist (10yr 6/4), some mottling white dry (10yr 8/1), light yellowish brown moist (10yr 6/4), loam, massive fine crumb flacked with lime, soft dry, friable moist, few medium vertical roots, +++ lime reaction, defused and wavy boundary.
					Note 3'-7' Weathered fractured sandstone, with lime mycelia. 7'-8' Weathered shale 8'-9' Coal 9'-14' Mudstone

REMARKS:

TYPICAL SOIL PROFILE

PROJECT Taylor Creek Site AREA Colorado TYPICAL PROFILE NO. VIII

(in)	Log	EC x 10^3	Exch. Na. Meg./100gm	Hori-zon	Soil profile description (Color, texture, structure, consistence, and variations, etc.)
0-5		.963	.35	A	Dark gray dry (5yr 4/1), very dark gray moist (5yr 3/1), loam, weak to moderate fine platy, soft dry, friable moist, abundant fine to very fine random roots, clear and smooth boundary.
5-16		.883	.83	A1	Dark grayish brown dry (10yr 4/2), dark grayish brown moist (10yr 4/2), some iron mottling brownish yellow (10yr 6/8), clay, strong medium prismatic peds, very hard dry, firm moist, continuous thick clay films, few fine and medium vertical roots, + lime reaction, clear and wavy boundary.
16-22		.2.83	2.45	A3	Dark grayish brown dry (10yr 4/2), dark grayish brown moist (10yr 4/2), some lime mottling white (10yr 8/1), clay, strong medium angular blocky, very hard dry, friable moist, continuous thick clay films, few fine and medium vertical roots, + lime reaction, clear and wavy boundary.
22-37		9.51	3.12	C	Black dry (7.5yr 2/0), black moist (7.5yr 2/0), some white mycelium mottling (7.5yr 8/0), clay, massive fine granular, slightly hard dry, firm moist, few medium vertical roots, the mycelium has a +++ lime reaction the clay has none, clear and smooth boundary.
37-60		-	-	D	Gray dry (7.5yr 5/0), dary gray moist (7.5yr 4/0), shale massive fine platy, slighty hard dry, friable moist, few medium vertical roots, abrupt and wavy boundary. Note 5'-6' Mudstone 6'-8' Sandstone

REMARKS: Stopped drilling at 8' due to sandstone (large cracks go from 0-30" about ½" wide)

TYPICAL SOIL PROFILE

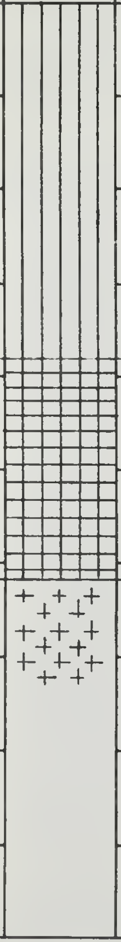
PROJECT Taylor Creek Site AREA Colorado TYPICAL PROFILE NO. IX

(in)	Log	EC x 10^3	Exch. Na. Meq./100gm	Hori-zon	Soil profile description (Color, texture, structure, consistence, and variations, etc.)
0-2.5	si	.929	.27	A	Dark grayish brown dry (10yr 4/2), very dark grayish brown moist (10yr 3/2), silt loam, weak fine platy, soft dry, friable moist, abundant fine and very fine random roots, clear and smooth boundary.
2.5-10	si	.975	.27	A1	Dark grayish brown dry (10yr 4/2), very dark grayish brown moist (10yr 3/2), silty clay loam, strong fine subangular blocky, hard dry, firm moist, few fine random roots, clear smooth boundary.
10-22		.420	.23	A$_2$	Dark grayish brown dry (10yr 4/2), dary brown moist (10yr 4/3), clay, moderate medium prismatic peds, very hard dry, firm moist, continuous thick clay films, few medium vertical roots, about 1% fragmented sandstone, top boundary abrupt and wavy, bottom boundary clear and smooth.
22-40		.354	.46	B	Olive dry (5y 5/3), olive moist (5y 5/3), some white lime mottling, clay, weak medium prismatic to strong medium subangular blocky, very hard dry, firm moist, few medium vertical roots, ++ lime reaction, clear and wavy boundary.
40-48	s i	.352	.46	C$_{ca}$	Olive dry (5y 5/3), olive moist (5y 4/3), some white mycelium (2.5y 8/0), silty clay, moderate medium subangular blocky, very hard dry, firm moist few medium vertical roots, about 20% fractured mudstone, +++ lime reaction, clear and wavy boundary.
					Note 4'-5' Shale - light gray 5'-6' Mudstone - light gray 6'-9' Shale - brownish gray 9'-12' Shale with small lenses of mudstone 12'-15' Shale dark gray 15'-20' Coal 20'-22' Carbonecous shale, black

REMARKS: Water table at 18.2' after one hour. (stopped drilling at 22' due to sandstone.)

TYPICAL SOIL PROFILE

PROJECT Taylor Creek Site AREA Colorado AUGER PROFILE NO. B

(in)	Log	EC x 10^3	Exch. Na. Meq./100gm		Soil profile description (Color, texture, structure, consistence, and variations, etc.)
0-22					Heavy clay texture, sticky and plastic when wet, hard when dry - Blocky structure except for thim platy surface. Slope = 6-8% hillside Vegetation: Sagebrush with grass understory
22-38					22 - 38" shale, weathered
					38 + sandstone

1
2
3
4
5

REMARKS: Not sampled

TYPICAL SOIL PROFILE

PROJECT Taylor Creek Site AREA Colorado AUGER PROFILE NO. B

(in)	Log	EC x 10^3	Exch. Na. Meq./100gm		Soil profile description (Color, texture, structure, consistence, and variations, etc.)
0-4	▧				Heavy clay loam texture, weak platy to crumb structure, soft dry; firm moist; and slightly sticky when wet. Vegetation: sagebrush with some rabbit brush and grass understory. Slope: 3% to northeast along ridge top - rolling off to 6-8%.
4-12 1	▥				Clay texture, angular blocky structure, sticky and plastic when wet - hard when dry
2 12-60 3 4 5	▦				12-24" Shale, weathered sticky and plastic 24-30" Shale mottled with fe stains 36-46" Shale, dark gray 46-58" Shale, organic poor quality coal 58-60" Sandy shale, nearly sandstone, very hard

REMARKS: Not sampled

TYPICAL SOIL PROFILE

PROJECT Taylor Creek Site AREA Colorado AUGER PROFILE NO. C

(in)	Log	EC x 10^3	Exch. Na. Meg./100gm		Soil profile description (Color, texture, structure, consistence, and variations, etc.)
0-8					Heavy clay texture, strong angular blocky, many roots, sticky and plastic wet, hard dry. Slope: 3-5% rolling to 6-12% where it breaks into the gullies, on up to 20% at steepest points. Vegetation: Juniper, sagebrush and grass understory.
8-60					8-30" Weathered shale, very hard sticky and plastic, gray mottling, weak lime zone of accumulation 30-48" Mudstone or very hard shale. 48-60" Sandy shale, moist hard to very hard.

REMARKS: Not sampled

LOG OF DRILL OR AUGER HOLE NO. AH-1 DATE 7-30-74

Project: Taylor Creek Area: Craig Colorado Location: 75'S 25'W of SW Cor Sec 9, T3N, R93W

Depth	Log	EC x 10³ & PH 1:5	Soil and Moteriol Description Texture, Structure, Color & etc.
0 1		.07 7.9	0-1 Silty Clay Loam, dark brown, dry, many fine to medium roots.
2		.10 8.6	1-2 Clay Loam, brown, dry, many fine to medium roots.
3.5		.10 9.2	2-3.5 Fine Sandy Loam, light brown, dry to damp, moderate lime - few medium size roots.
5 8		.08 9.4	3.5-8 Sandstone, weathered, buff color, soft, dry, some Fe mottling.
10 13		.08 9.3	8-13 Sandstone, weathered, soft, buff color, some Fe mottling
14	Coal		13-14 Coal, damp, organic, black
15 17.5	shale	.14 8.6	14-17.5 Shale, damp, dark gray, few Fe stains some weathering
19	sandy shale	.10 8.7	17.5-19° - Sandy Shale, gray, some mottling and weathering
20	mud stone	.12 8.9	19-20 Mudstone, grayish brown, very hard, layered shale an mudstone.
25			Stopped at 20'

LOG OF DRILL OR AUGER HOLE NO. AH-2 DATE 7-30-74

Project: Taylor Creek Area: Craig, Colorado Location: 650 N of SE Cor of Sec 4, T3N, R93W

Depth	Log	EC x 10^3 & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 0.8		.03 7.6	0-0.8' Loam, brown, dry, about 1% fragmented sandstone on surface, many fine roots
3		.06 8.5	0.8-3' Fine Sandy Loam, light brown, dry, soft, many fine to medium roots.
5		.05 8.9	3-5' Sandstone, weathered, damp, some Fe mottling, fairly hard.
			Stopped at 5' due to hard sandstone
10			
15			
20			
25			

LOG OF DRILL OR AUGER HOLE NO. AH-3 DATE 7/30/74

Project: Taylor Creek Area: Craig, Colorado Location: 200'W of E ¼ Cor of Sec 4, T3N, R93W

Depth	Log	EC x 10^3 & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 2		.09 8.3	0-2' Clay, brown, dry, small layer of hard shale near bottom, many fine roots
3		.10 8.9	2-3 Clay Loam, light brown, dry, weak lime reaction, slightly hard, many fine roots.
5	shale	2.80 8.4	3-5 Shale, gray, with small lenses of black carbonaceous shale, moist. some white lime mottling, hard, few medium roots.
6	sandy shale	.30 9.1	5-6 Sandy Shale, light gray, damp, hard
8.7	shale	.36 8.9	6-8.7 Shale, weathered, moist, gray, some Fe mottling, hard
10	coal	.85 8.4	8.7-10 Coal
14	shale	.41 8.2	10-14 Shale, weathered, gray, moist, hard, some Fe mottling
15 18	coal	.28 4.4	14-18 Coal
20	mud stone	.18 7.3	18-20 Mudstone, gray, damp, very hard to drill
25			Stopped at 20' due to Mudstone, very hard, unable to drill through it.

LOG OF DRILL OR AUGER HOLE NO. AH-4 DATE 7-31-74

Project: Taylor Creek Area: Craig, Colorado Location: 1,000'N - 1900 W
S.E. Cor Sec. 4, T3N-R93W

Depth	Log	EC x 10³ & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 1.8		.03 8.1	0-1.8 Clay Loam, brown, dry, soft
3		.09 8.9	1.8-3 Clay, weathered shale, soft, some lime accumulation, few roots, damp, brown
4		.06 9.1	3-4 Sandstone, weathered, hard, damp, light brown.
5 6	shale	.86 8.4	4-6 Shale, gray, some Fe mottling, damp, at 6' small lenses of carbonaceous shale.
9	shale	.35 8.7	6-9 Shale, sandy, gray, some Fe mottling, at 7' a small lense of sandstone, hard, stopped at 9' because of sandstone.
10			
15			
20			
25			

LOG OF DRILL OR AUGER HOLE NO. AH-5 DATE 7-31-74

Project: Taylor Creek Area: Craig, Colorado Location: 2400'W 2100 N -
S.E. Cor Sec. 4, T3N, R93W

Depth	Log	EC x 10^3 & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 1		.09 8.3	0-1 Clay Loam, brown, dry, soft, about 10% fragmented sand stone on surface
3		1.45 8.1	1-3 Clay weathered shale, gray, some accumulation of lime, lense of organic matter near 3' dark brown, damp, soft.
5		.52 8.7	3-5 Clay, light redish color, large accumulation of Fe mottling, soft, damp.
7	shale	.84 8.6	5-7 Shale, weathered, gray, some small lenses of black organic matter, moist, soft, little accumulation of Fe mottling
10 11.5		.43 8.7	7-11.5 Sandstone, weathered, tan, some Fe mottling, moist. Stopped at 11.5' because of hard sandstone
15 20 25			

LOG OF DRILL OR AUGER HOLE NO. AH-6 DATE 7-31-74

Project: Taylor Creek Area: Craig, Colorado Location: 2250'W 1850'S of NE Cor Sec. 4, T3N, R93W

Depth	Log	EC x 10³ & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0		.09 8.4	0-1 Clay, brown to gray, dry, slightly hard.
3		.08 8.7	1-3 Sandstone, weathered, very weakly cemented, almost weathered to a fine sandy loam, soft, some Fe mottling, dry
5	shale	.15 8.9	3-5 Shale, weathered, large accumulation of lime from 3' to 4', some Fe mottling, damp, hard, light gray.
7.5	shale	.88 8.3	5-7.5 Shale, weathered, gray to brown, some Fe mottling, small lenses of dark brown organic matter from 6' to 7', fairly hard, damp
9	mud stone	1.58 8.0	7.5-9 Mudstone, light gray, large accumulation of Fe mottling, very hard, dry
10	shale	2.13 7.6	9-10 Shale, organic, dark brown, soft, moist
15	shale	.72 7.2	10-15 Shale, gray, hard, dry Stopped at 15' because of hard dry shale
20			
25			

LOG OF DRILL OR AUGER HOLE NO. AH-7 DATE 8-1-74

Project: Taylor Creek Area: Craig Colorado Location: 1300'E 1300'S of N.W.
Cor of Sec. 3, T3N, R93W

Depth	Log	EC x 10³ & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 1		.15 8.1	0-1 Clay, some organic matter, hard, dry, some roots.
2		1.44 8.4	1-2 Clay, weathered, dark gray, some accumulation of lime, moist, very hard, roots.
3		3.27 9.0	2-3 Clay, weathered, gray, large accumulation of lime, roots.
4	mud stone	.70 8.6	3-4 Mudstone, some Fe mottling, light brown, soft.
5	shale		4-5 Shale, high organic, black, hard, some Fe mottling.
		.44 8.9	5-9.5 Sandstone, highly decomposed, weathered, light gray to buff, damp, slightly hard.
9.5		.38 8.8	9.5-10 Sandstone, very hard, rock-like, damp.
10			
12.5		.30 9.0	10-12.5 Sandstone, highly decomposed, weathered, light tan, damp, slightly hard.
			Stopped at 12.5' because of very hard sandstone.
15			
20			
25			

LOG OF DRILL OR AUGER HOLE NO. AH-8 DATE 8-1-74

Project: Taylor Creek Area: Craig, Colorado Location: 1800'E 100'S, N.W. Cor Sec. 3, T3N, R93W

Depth	Log	EC x 10^3 & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 1		.05 8.0	0-1 Clay Loam, brown, dry, soft
2		.04 7.7	1-2 Sandy Clay Loam, tan, dry, some Fe mottling.
3		.04 7.8	2-3 Clay, weathered, light brown, considerable Fe mottling, moist.
5 5.5		.05 8.9	3-5.5 Sandstone , weathered, light tan, damp, fairly hard
6	organic		5.5-6 Organic Matter, black, damp, soft
10		.05 8.9	6-10 Sandstone, weathered, light tan, damp, fairly hard. Stopped at 10' because of very hard sandstone.
15			
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LOG OF DRILL OR AUGER HOLE NO. AH-9 DATE 8-6-74

Project: Taylor Creek Area: Craig, Colorado Location: 1350 S, 1750 E N.W.
Cor of Sec. 3, T3N, R93W

Depth	Log	EC x 10^3 & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0		.18 8.8	0-2 Clay, heavy, brownish gray, dry, hard, many roots.
2		.75 9.0	2-3 Clay, light brown, dry hard, some Fe mottling, many roots.
3		.52 9.2	3-4.5 Clay Loam, dry, fairly hard, light brown, large accumulation of Fe mottling, some roots.
4.5			
5			Stopped at 4.5' because of very hard mud stone.
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LOG OF DRILL OR AUGER HOLE NO. AH-10 DATE 8-6-74

Project: Taylor Creek Area: Craig, Colorado Location: 2480 E. 1450 S. N.W. Cor. Sec. 3, T3N, R93W

Depth	Log	EC x 10^3 & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0		.10 8.4	0.2 Clay, light, brown, dry, fairly hard, some Fe mottling, many roots.
2	shale	.30 8.9	2-5 Shale, weathered, large accumulation of lime and some Fe mottling, hard, gray, many roots.
5	shale	1.09 8.5	5-7 Shale, organic, weathered, large accumulation of lime from 6' - 7', black from 5'-6' dark gray to 7', some Fe mottling, some roots.
7	mud stone	1.56 8.2	7-8 Mudstone, weathered, light brown, large accumulation of Fe mottling, very hard.
8			
10			Stopped at 8' because of very hard mudstone.
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LOG OF DRILL OR AUGER HOLE NO. AH-11 DATE 8-6-74

Project: Taylor Creek Area: Craig, Colorado Location: 3100 S 3300 E', N.W. Cor Sec. 3, T3N, R93W

Depth	Log	EC x 10³ & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 1		.09 7.6	0-1 Silty Clay Loam, brown, soft, dry, many roots
3		.06 7.5	1-3 Clay, weathered, light brown and hard, dry, large accumulation of Fe mottling, some roots.
4	shale	.14 7.8	3-4 Shale, weathered, gray, moist, some Fe mottling.
5 6		.12 8.2	4-6 Clay, light, brown, some Fe mottling and a little accumulation of Lime, damp
7		.12 8.3	6-7 Sandy Clay Loam, brown, light Fe mottling, some accumulation of lime, damp
9.5		.17 8.4	7-9.5 Clay, light, brown, light Fe mottling, large accumulation of lime, damp
10 12	mud stone	.15 8.4	9.5-12 Mudstone, light, gray, weathered, some Fe mottling, indurated, hard, some accumulation of lime, damp
15 16.5	shale	.22 8.4	12-16.5 Shale, weathered, light gray, damp, some Fe mottling and lime accumulation.
19	organic shale	.59 8.1	16.5-19 Shale, organic, dark brown to gray, damp, some Fe mottling.
20 25			Stopped at 19.5' because of sandstone.

LOG OF DRILL OR AUGER HOLE NO. AH-12 DATE 8-6-74

Project: Taylor Creek Area: Craig, Colorado Location: 2850's, 4570'E, N.W. Cor Sec. 3, T3n, R93W

Depth	Log	EC x 10³ & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 1		.06 7.3	0-1 Loam, brown, dry, soft, many roots.
3.5		.04 7.2	1-3.5 Clay, light, brown, dry, medium hard, some Fe mottling.
4.5		.09 7.8	3.5-4.5 Sandstone, very hard, damp, tan.
5			Stopped at 4.5; because of very hard sandstone.
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LOG OF DRILL OR AUGER HOLE NO. AH-13 DATE 8-7-74

Project: Taylor Creek Area: Craig, Colorado Location: 300'N, 320'W, S.E. Cor Sec 3, T3N, R93W

Depth	Log	EC x 10^3 & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 1		.11 8.2	0-1 Clay Loam, brown, dry, soft, many roots.
2		.05 8.4	1-2 Clay, brown, dry, fairly hard, many roots
3		.08 8.6	2-3 Clay, gray, dry, hard, come roots, large accumulation of lime, weathered, some Fe mottling
4		.08 8.9	3-4 Clay Loam, light gray, damp, fairly hard, some Fe mottling.
5 8		.07 8.9	4-8 Sandstone, weathered, light brown, some Fe mottling, damp.
9	org. shale	.18 8.5	8-9 Shale , organic, black to gray, moist, some Fe mottling,
10	shale	.10 8.7	9-10 Shale, gray, hard, moist
11.5	shale	.09 8.7	10-11.5 Shale, weathered, damp, hard, light brown, large accumulation of Fe mottling.
15	shale	.10 8.8	11.5-15 Shale, gray, damp, very hard.
17	shale	.10 8.8	15-17 Shale, light brown, Fe mottling, damp, very hard.
20 25			Stopped at 17' because of very hard mud stone or sandstone

LOG OF DRILL OR AUGER HOLE NO. AH-14 DATE 8-7-74

Project: Taylor Creek Area: Craig, Colorado Location: 1400' N 800'E S.W. Cor of Sec. 2, T3N, R93W

Depth	Log	EC x 10^3 & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 3.5		1.21 8.0	0-3.5 Clay, heavy, light gray to dark gray, hard, dry, some accumulation of lime from 2-3.5, some Fe mottling at about 3'.
5 7		.91 8.4	3.5-7 Clay Loam, light brown to yellowish tan, damp, slightly hard, a few layers of hard mud stone, Fe mottling
9	shale	.18 9.1	7-9 Shale, weathered, gray, highly liminated, hard, some Fe mottling.
9.5 10			9-9.5 Sandstone, stopped at 9.5', very hard, no sample.
15			
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LOG OF DRILL OR AUGER HOLE NO. AH-15 DATE 8-7-74

Project: Taylor Creek Area: Craig, Colorado Location: 1825'S 330 W, N.E. Cor Sec 10, T3N, R93W

Depth	Log	EC x 10³ & PH 1:15	Soil and Material Description Texture, Structure, Color & etc.
0 1		.05 8.1	0-1 Clay, heavy, brown, dry, hard, about 5% fragmented sandstone on surface, many roots
2.5		.11 8.8	1-2.5 Clay, heavy, gray, dry, hard, large accumulation of lime
3	mudstone		2.5-3 Mudstone, weathered, hard, dry, some Fe mottling
5	shale	.21 8.9	3-5 Shale, weathered, gray, dry, hard, some Fe mottling and lime accumulations
7		.12 9.0	5-8 Sandstone, weathered, tan, dry, hard, some Fe mottling
10			Stopped at 7' because of hard sandstone
15			
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LOG OF DRILL OR AUGER HOLE NO. AH-16 DATE 8-7-74

Project: Taylor Creek Area: Craig, Colorado Location: 2910S, 425W, N.E. Cor Sec. 10, T 3 N, R 93 W.

Depth	Log	EC x 10³ & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 1		.11 8.6	0-1 Clay Loam, brown, dry, medium hard, many roots.
2		.10 8.9	1-2 Clay, heavy, light brown, dry, Fe mottling, some accumulation of lime.
4.5	shale	.21 8.9	2-4.5 Shale, weathered, gray, damp, hard, some Fe mottling, large accumulation of lime.
5	mudstone		4.5-5 Mudstone, very hard, light brown, Fe mottling dry.
9	shale	.42 8.5	5-9 Shale, weathered, dark gray, hard, damp, some Fe mottling, at 8' a lense of organic matter.
10	mud stone	.18 8.8	9-10 Mudstone, gray, very hard, damp, some Fe mottling.
11	org. shale	.20 8.6	10-11 Shale, organic, dark brown, hard, damp, highly laminated, some Fe mottling.
15 17.5	shale	.12 8.8	11-17.5 Shale, weathered, gray, hard, damp, laminated shale and iron, large accumulation of Fe mottling.
18	mudstone		17.5-18 Mudstone, very hard, gray, Fe mottling.
19	shale	.11 8.7	18-19 Shale, weathered, gray, hard, damp, large accumulation of Fe mottling, laminated.
20 21	org. shale	.10 8.5	19-21 Shale, organic, dark brown, damp, hard, laminated.
23	shale	.10 8.5	21-23 Shale, light brown, very hard, damp, some Fe mottling.
25			Stopped at 23', very hard shale.

LOG OF DRILL OR AUGER HOLE NO. AH-17 DATE 8-8-74

Project: Taylor Creek Area: Craig Colorado Location: 2200'S, 2500'W, NE Cor Sec 10, T 3 N, R93W

Depth	Log	EC x 10^3 & PH	Soil and Material Description Texture, Structure, Color & etc.
0 1		1.5 .05 7.7	0-1 Clay loam, brown, medium hard, dry, many roots.
2		.04 8.0	1-2 Clay, heavy, brown, hard, dry, many roots.
3		.12 8.8	2-3 Clay, heavy, hard, dry, gray, high accumulation of lime, some Fe mottling.
5	Mud Stone	.63 8.2	3-7 Mudstone, weathered, laminated with lenses of fine sand, hard, large accumulation of Fe mottling, light brown, damp.
7 7.8		.22 8.4	7-7.8 Sandstone, tan, damp, hard.
10 15 20 25			Stopped at 7.8' because of very hard sandstone.

LOG OF DRILL OR AUGER HOLE NO. AH-18 DATE 8-8-74

Project: Taylor Creek Area: Craig, Colorado Location: 225'S, 1100'E, N.W. Cor Sec. 10, T 3 N, R 93 W.

Depth	Log	EC x 10³ & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 1		.06 7.8	0-1 Clay, heavy, dry, hard, many roots.
3	shale	.45 8.3	1-3 Shale, weathered, gray, damp, hard, some accumulation of lime at 3', small Fe mottling.
5 7	shale	.46 8.4	3-7 Shale, weathered, gray to light brown, damp, hard, large accumulation of lime, at 6.5' there was a large accumulation of Fe about 2" thick, rust color.
10	mud stone	.23 8.8	7-10 Mudstone, light gray, very hard, damp, some Fe mottling.
11		.14 8.8	10-11 Sandstone, very hard, tan.
15 20 25			Stopped at 11' because of sandstone.

LOG OF DRILL OR AUGER HOLE NO. AH-19 DATE 8-13-74

Project: Taylor Creek Area: Craig, Colorado Location: 1000 S, 2550 E, N.W. Cor of Sec. 10, T 3 N, R 93 W.

Depth	Log	EC x 10³ & PH	Soil and Material Description Texture, Structure, Color & etc.
0 2		1:5 .12 8.4	0-2 Clay, heavy, brown, dry, hard, some lime accumulation and light mottling.
4	shale	.17 9.0	2-4 Shale weathered, gray, hard, damp, some Fe mottling and lime accumulation.
5 8	mud stone	.33 8.7	4-8 Mudstone, weathered, light tan, hard, damp, considerable Fe mottling.
9	org. shale	.73 7.3	8-9 Shale, organic, black, soft, moist, highly laminated.
10	coal	.39 5.9	9-10 Coal, wet.
11	org. shale	.16 7.5	10-11 Shale, organic, black, moist, soft, highly laminated.
14	mud stone	.08 7.9	11-14 Mudstone, weathered, gray, very hard, damp, some Fe mottling.
15	shale	.08 8.1	14-15 Shale, gray, moist, very hard, some Fe mottling.
16	mud stone	.10 8.4	15-16 Mudstone, very hard, gray to light brown, dry.
20 25			Stopped at 16' because of very hard mudstone.

LOG OF DRILL OR AUGER HOLE NO. AH-20 DATE 8-13-74

Project: Taylor Creek Area: Craig Colorado Location: Approx Center of Sec 9, T 3 N, R 93 W.

Depth	Log	EC x 10³ & pH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0		.04 7.5	0-1 Clay loam, brown, dry, soft, many roots.
1		.12 8.6	1-2 Clay, heavy, brown, dry, hard, some light Fe mottling, some roots.
2	Shale	.70 8.6	2-7 Shale, weathered, dark gray to light gray, damp, hard some accumulation of lime at about 3', Fe mottling, some roots.
5			
7		.17 9.0	7-9.5 Sandstone, weathered, light brown, hard, damp.
9.5			Stopped at 9.5' because of hard sandstone.
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25			

LOG OF DRILL OR AUGER HOLE NO. AH-21 DATE 8-13-74

Project: Taylor Creek Area: Craig, Colorado Location: 1400'S, 1800W, N.E. Cor Sec. 9, T 3 N, R 93 W.

Depth	Log	EC x 10³ & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 1		.07 8.0	0-1 Clay Loam, brown, dry, medium soft, many roots.
2		.15 8.2	1-2 Clay, heavy, brown, dry, hard, some roots.
3		1.46 8.3	2-3 Clay, light, brown, damp, medium hard, accumulation of lime and Fe mottling.
5 6		.06 8.7	3-6 Sandstone, weathered, hard, light brown, damp
10 15 20 25			Stopped at 6' because of hard sandstone.

LOG OF DRILL OR AUGER HOLE NO. AH-22 DATE 8-13-74

Project: Taylor Creek Area: Craig, Colorado Location: 3000 E on ℄ of N.E. Cor Sec 9, T 3 N, R 93 W.

Depth	Log	EC x 10³ & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 1		.05 8.0	0-1 Clay Loam, light, brown, soft, dry, many roots.
2		.07 8.3	1-2 Clay, heavy, brown, dry, hard, many roots.
3	org. shale	.12 8.3	2-3 Shale, organic, weathered, dark brown, dry.
5	shale	.84 8.4	3-5 Shale, weathered, gray, hard, large accumulation of lime, some Fe mottling.
6.5		.53 8.6	5-6.5 Sandstone, weathered, damp, medium hard.
7	mudstone		6.5-7 Mudstone, some Fe mottling.
9		.37 8.8	7-9 Sandstone, weathered, light gray, damp, hard, some Fe mottling.
10			Stopped at 9' because of hard sandstone.
15			
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LOG OF DRILL OR AUGER HOLE NO. AH-23 DATE 8-13-74

Project: Taylor Creek Area: Craig, Colorado Location: 700 E, 250 W of N.W. Cor Sec 4, T 3 N, R 93 W

Depth	Log	EC x 10³ & PH	Soil and Material Description Texture, Structure, Color & etc.
0 2	Mud stone	1:5 .10 8.8	0-2 Mudstone, highly decomposed and weathered, condsiderable accumulation of lime, fairly hard, dry, many roots.
3		.10 8.9	2-3 Clay, heavy, damp, hard, gray, some accumulation of Fe mottling.
5		.11 8.9	3-5 Clay, light brown, damp, large accumulation of Fe mottling (decomposed weathered shale 2'-5').
7	shale	.12 9.1	5-7 Shale, weathered, moist, gray, some Fe mottling.
10	Coal	.55 8.6	7-10 Coal, weathered, soft, moist, poor quality.
13.5	shale	.19 8.9	10-13.5 Shale, gray, damp, hard, many lenses of fine sand, laminated.
15 20 25			Stopped by sandstone at 13.5'

LOG OF DRILL OR AUGER HOLE NO. AH-24 DATE 8-13-74

Project Taylor Creek Area: Craig, Colorado Location: 1250 E, 200'S of W¼ Cor Sec 4, T 3 N, R 93 W.

Depth	Log	EC x 10^3 & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 3		.19 9.0	0-3 Clay, heavy, light gray to dark gray, dry, hard, many roots.
4	mud stone	.31 9.0	3-4 Mudstone, light brown, dry, hard, broken, heavy Fe mottling.
5 6	shale	1.54 8.8	4-6 Shale, weathered, damp, hard, some Fe mottling.
7	mud stone	.83 8.9	6-7 Mudstone, light brown, damp, hard, broken.
10 11	shale	.75 8.7	7-11 Shale, weathered, gray, damp, hard, some Fe mottling.
13	mud stone	.69 8.6	11-13 Mudstone, weathered, damp, hard, tan, some Fe mottling.
14	mud stone	.42 8.6	13-14 Mudstone, weathered, damp, hard, tan, considerable Fe mottling.
15	shale	.53 8.6	14-15 Shale, weathered, gray, damp, hard, some Fe mottling.
16	mud stone	.42 8.6	15-16 Mudstone, light brown, very hard, damp, some Fe mottling.
20 25			Stopped at 16' because of hard mudstone.

LOG OF DRILL OR AUGER HOLE NO. AH-25 DATE 8-14-74

Project: Taylor Creek Area: Craig Colorado Location: 250 E, 700 N-W $\frac{1}{4}$ Cor Sec 9, T 3N, R 93 W.

Depth	Log	EC x 10³ & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 1		.06 7.9	0-1 Loam, dry, soft, many roots.
2.4		.04 7.6	1-2.4 Clay loam, dry, brown, medium hard, some Fe mottling, many roots.
4		.06 8.0	2-4.4 Sandstone, hard, light brown, some Fe mottling.
			Stopped at 4' because of hard sandstone.
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LOG OF DRILL OR AUGER HOLE NO. AH-26 DATE 8-14-74

Project: Taylor Creek Area: Craig Colorado Location: 775'S, 500'E, N.W.
Cor Sec 10, T 3 N, R 93 W.

Depth	Log	EC x 10³ & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 1		.07 7.9	0-1 Loam, dry to damp, brown, soft, many roots.
		.07 8.1	1-5 Clay loam, light, damp, soft, brown, many roots.
5 9		.09 8.0	5-9 Clay, moist, brown to light brown, hard, many roots.
10 13		.12 8.4	9-13 Silty Clay loam, light gray, wet, medium soft, few roots, some small lenses of clay near 12'
15 17		.09 8.6	13-17 Clayey gravel, alluvial material, gray to light brown, wet, clay matrix, considerable Fe mottling.
18		.07 8.6	17-18 Sandstone, weathered, tan, hard, saturated,
20 25			Stopped at 18' because of sandstone. (Water at 17.6' - after one hour water table at 16.7')

LOG OF DRILL OR AUGER HOLE NO. AH-27 DATE 8-14-74

Project: Taylor Creek Area: Craig Colorado Location: 950'W, 2100'S, N.E. Cor Sec 9, T 3 N, R 93 W.

Depth	Log	EC x 10³ & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 3		.13 8.6	0-3 Clay, heavy, brown to gray, dry, hard, many roots.
5	Shale	.77 8.3	3-5 Shale, weathered, gray, damp, some roots, large accumulation of lime, some Fe mottling, hard.
7		.28 8.8	5-7 Sandstone, weathered, tan, dry, hard.
10 15 20 25			Stopped at 7' because of hard sandstone.

LOG OF DRILL OR AUGER HOLE NO. AH-28 DATE 8-27-74

Project: Taylor Creek Area: Craig, Colorado Location: 640'S, 2050'W N.E. Cor Sec. 4, T 3 N, R 93 W

Depth	Log	EC x 10³ & PH 1:5	Soil and Material Description Texture, Structure, Color & etc.
0 1		.05 8.0	0-1 Clay Loam, brown, dry, soft, many roots
3.5		.04 7.9	1-3.5 Clay, heavy, brown, hard, damp, some Fe mottling.
4	shale		3.5-4 Shale, weathered, hard, dry, some Fe mottling.
5 7		.25 8.5	4-7 Clay, light, dry, tan, large accumulation of lime, some Fe mottling (decomposed weathered shale).
9.5		.57 8.4	7-9.5 Sandstone, weathered, medium hard to hard, light brown to tan, damp.
10 10.7	shale	.72 8.6	9.5-10.7 Shale, gray, damp, hard, large accumulation of lime, some Fe mottling.
12	shale	.53 8.7	10.7-12 Shale, light brown, damp, hard, some accumulation of lime and Fe mottling.
15	shale	1.54 8.2	12-15 Shale, dark gray, hard, damp, some organic matter, large accumulation of lime, some Fe mottling.
16	org. shale	1.15 8.2	15-16 Shale, organic matter, black, moist, hard.
18	shale	.39 8.4	16-18 Shale, gray, hard, moist, some accumulation of lime and Fe mottling.
19.6	org. shale	.39 8.4	18-19.6 Shale, organic matter, black, moist, fairly hard.
20 21	mud stone	.25 8.2	19.6-21 Mudstone, gray, very hard.
25			Stopped at 21' because of mudstone.

LOG OF DRILL OR AUGER HOLE NO. AH-29 DATE 8-27-74

Project: Taylor Creek Area: Craig, Colorado Location: 2350'N, 1750 E, S.W. Cor Sec. 2, T 3 N, R 93 W

Depth	Log	EC x 10³ & PH 1:5	Soil and Material Description Texture, Structure, Color & etc
0 1		.08 8.2	0-1 Clay loam, light brown, dry, soft.
2		.08 8.7	1-2 Silty Clay Loam, light tan, dry, soft to medium hard, some accumulation of lime.
3		.08 8.7	2-3 Silty Clay Loam, light brown, dry medium hard, small lense of sandstone at about 3'
3.5	shale		3-3.5 Shale, organic, dark gray, damp, soft, some Fe mottling.
5		.11 8.4	3.5-5 Clay, light, tan, damp, some accumulation of lime, considerable Fe mottling.
7	mud stone	.08 9.1	5-7 Mudstone, light gray, damp, fairly hard, some accumulation of lime.
8	mud stone	.10 9.0	7-8 Mudstone, tan, damp, hard, large accumulation of Fe and some lime.
10	shale	.14 9.0	8-10 Shale, gray, damp, weathered, some Fe mottling, some accumulation of lime.
11	shale	.12 9.1	10-11 Shale, light gray, damp, hard, some accumulation of lime, heavy Fe mottling.
15 19	shale	.17 8.8	11-19 Shale, damp, weathered, hard, laminated, heavy Fe mottling, some lime accumulation.
20 22	Org. shale	.10 8.1	19-22 Shale, organic, black, moist, soft, at 21.5' a small lense of mudstone with heavy Fe mottling.
25	shale	.12 8.4	22-25 Shale, dark gray, laminated, damp, hard, weathered. Stopped at 25', limit of drill.

LOG OF DRILL OR AUGER HOLE NO. AH-30 DATE 9-10-74

Project: Taylor Creek Area: Craig Colorado Location: 700'E 250'S N.W. Cor Sec 3, T 3 N, R 93 W

Depth	Log	EC x 10^3 & PH	Soil and Material Description Texture, Structure, Color & etc.
0 1		1.5 .10 8.5	0-1 Clay, brown, dry, hard, contains some organic matter.
3		.26 8.7	1-3 Clay, heavy, light brown, dry, hard, light Fe mottling.
4	shale	2.57 8.0	3-4 Shale, weathered, gray, hard, large accumulation of lime, some Fe mottling, damp.
5	Org. shale	2.06 7.9	4-5 Shale, organic, dark gray, hard, damp, weathered, some accumulation of lime.
8	shale	.58 8.3	5-8 Shale, weathered, light gray, damp, hard, some Fe mottling.
10 15 20 25			Stopped at 8' because of very hard mudstone

LOG OF DRILL OR AUGER HOLE NO. AH-31 DATE 8-27-74

Project: Taylor Creek Area: Craig Colorado Location: 950'N, 1400'E, S.W. Cor Sec 34, T 3 N, R 93 W.

Depth	Log	EC x 10^3 & PH 1:5	Soil and Material Description Texture, Structure, Color & etc
0 2			0-2 Fine Sandy loam, tan, dry, soft.
4	Shale		2-4 Shale, weathered, dry, light gray, large accumulation of lime, some Fe mottling, hard.
5 6			4-6 Clay, light, dry, light brown, some accumulation of lime and Fe mottling (decomposed weathered shale 4'-6').
10 14.5	Shale		6-14.5 Shale, weathered, dark gray, dry to damp, hard, large accumulation of lime and Fe mottling.
15 20 25			Stopped at 14.5' because of sandstone. Note: This hole not on lease.

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH

LAB. No.	Boring Number	Depth Inch Feet	Field Text.	Hyd. Cond.		Set. Vol.	pH @ 25° C			Saturation Extract					1:5 Ext.			G.R. meq / 100 g	Ca+Mg 1:5 meq./100 g	Tension in Bars			Particle Size			
				6 Hr.	24 Hr.					ECe @ 25°C.	Na. meq./l.	Ca+Mg. meq./l.	SAR		EC5 @ 25°C.	Ca+Mg. meq./l.	SAR Est.					15	Sand %	Silt %	Clay %	Lab. Text. Class
				in/hr.	in/hr.	ml.	1:5	Paste.	.01 M CaCl2				True	Ext.						% Moisture						
S-D1-1-74	DH'101	0-1	Clay Loam	.34	.26	23	7.4		6.8						.03							12.5				None
S-D1-2-74		1-2	Clay	.05	.03	31	7.9		7.0						.04							18.2				None
S-D1-3-74		2-8	Shale	.17	.17	30	8.9		7.8	2.62	6.8	25.3	1.9		.48							22.4				None
S-D1-4-74		8-12	Shale	.10	.10	29	8.2		7.7	1.61	4.0	14.9	1.5		.72							18.0				None
S-D1-5-74		13-14	Shale	.14	.14	28	6.8		6.2						.22							17.6				None
S-D1-6-74		14-16	Shale	.05	.05	29	8.3		7.1						.13							17.8				None
S-D1-7-74		16-25.8	Sand-stone	.07	.09	23	8.9		7.9						.13							7.7				Very weak
S-D1-8-74		25.8-34.5	Shale	.25	.27	27	8.6		7.8						.20							13.0				None
S-D1-9-74		34.5-41.1	Mud-stone	.20	.19	23	8.4		7.6						.20							8.4				None
S-D1-10-74		41.1-51.5	Shale	.09	.08	26	8.7		7.4						.13							11.7				Very weak
S-D1-11-74		55.4-64.1	Mud-stone	.04	.05	24	9.1		7.8						.09							8.3				Very weak
S-D1-12-74		64.1-70.2	Mud-stone	.22	.26	18	8.7		7.7						.12							4.1				Mod.
S-D1-13-74		70.2-83	Mud-stone	.12	.12	23	9.2		7.8						.12							8.5				Mod.
S-D1-14-74		83-92.5	Sand-stone	.17	.19	17	9.4		8.0						.10							2.6				Mod.
S-D1-15-74		92.5-110.2	Mud-stone	.09	.09	23	8.8		7.6						.14							9.6				Mod.
S-D1-16-74		110.2-124.5	Mud-stone	.05	.05	26	9.1		7.7						.12							10.2				Mod.
S-D1-17-74		124.5-138.4	Sand stone	.12	.15	20	9.1		7.8						.11							5.4				Mod.
S-D1-18-74		138.4-158.7	Sand stone	.30	.35	18	9.4		8.0						.09							2.2				Mod.
S-D1-19-74		158.7-166.5	Shale	.22	.30	26	8.9		7.7						.13							11.2				Mod.
S-D1-20-74		166.5-170.8	Sand-stone	.07	.10	19	9.5		8.0						.23							3.9				Very weak
S-D1-21-74		170.8-196.5	Shale	0	.05	34	9.6		8.0						.19							10.0				Very weak
S-D1-22-74		208.4-217	Mud-stone	0	Wet 1" 0	114	9.6		7.8						.20							11.8				Very weak

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH

C.S.U. LAB. No.	Boring Number	Depth Inch Feet	Field Text.	Hyd Cond.		Set. Val.	pH @ 25° C			Saturation Extract					1:5 Ext.			G.R.	Ca+Mg 1:5	Tension in Bars			Particle Size			
				6 Hr.	24 Hr.					ECe @	Na.	Ca+Mg.	SAR		EC5 @	Ca+Mg	SAR	meq./	meq./			15	Sand	Silt	Clay	Lab. Text. Class
				in/hr.	in/hr.	ml.	1:5	Paste.	.01 M Ca Cl2	25°C.	meq./l.	meq./l.	True	Ext.	25°C.	meq./l.	Est.	100 g	100 g.	% Moisture			%	%	%	
S-D2-1-74	DH-102 1	0-1	Clay	.22	.12	27	7.0		6.7						.06							16.6				
S-D2-2-74	2	1-3	Clay	.13	.18	33	8.6		7.8						.19							20.1				
S-D2-3-74	3	3-4	Clay	.20	.30	31	8.1		7.9	7.26	28.8	82.4	4.5		2.82							21.9				
S-D2-4-74	4	4-4.8	Sand-stone	.16	.18	27	8.0		7.9	7.48	29.2	79.2	4.6		2.36							17.5				
S-D2-5-74	5	4.8-8	Shale	.07	.07	28	8.1		7.9	5.83	18.0	64.2	3.2		.90							17.6				
S-D2-6-74	6	8-9	organic shale	.24	.26	34	7.9		7.8	5.57	14.0	63.4	2.5		1.30							22.2				
S-D2-7-74	7	9-11	Shale	.11	.16	32	8.1		7.7						.39							18.9				
S-D2-8-74	8	11-14	Sand-stone	.12	.10	23	8.6		7.9						.22							9.0				
S-D2-9-74	9	15.3-17.6	Mud-stone	.07	.07	25	8.3		7.8						.28							9.1				
S-D2-10-74	10	17.6-33	Sand-stone	.03	.03	27	7.1		6.8						.29							13.6				
S-D2-11-74	11	34.3-47.8	Sand-stone	.22	.22	19	8.8		7.8						.09							3.5				
S-D2-12-74	12	47.8-55.6	Shale	.04	.03	29	8.2		7.5						.16							13.4				
S-D2-13-74	13	55.6-58.5	Sand-stone	.14	.14	19	8.4		7.9						.18							4.1				
S-D2-14-74	14	58.5-64.4	Shale	.05	.05	25	8.3		7.8						.19							10.3				
S-D2-15-74	15	64.4-69.8	Shale	.07	.07	23	8.4		7.9						.20							7.3				
S-D2-16-74	16	69.8-85.4	Shale	.16	.16	18	8.6		8.0						.13							2.6				
S-D2-17-74	17	85.4-88.2	Shale	.02	.02	30	8.6		7.8						.23							7.5				
S-D2-18-74	18	88.2-97	Sand-stone	.13	.12	18	8.6		8.0						.15							3.2				
S-D2-19-74	19	97-109.2	Shale	.02	.02	26	8.7		7.9						.21							7.6				
S-D2-20-74	20	109.2-111.7	Sand-stone	.10	.10	19	8.7		8.1						.15							2.7				
S-D2-21-74	21	111.7-116.6	Shale		Wet 7 CM	46	8.6		7.7						.40							11.8				
S-D2-22-74	22	116.6-133	Shale		Wet 2.5CM	86	9.3		8.2	1.62	16.4	0			.54							22.1				
S-D2-23-74	23	147.6-167.3	Shale		Wet 2.5CM	110	9.3		8.1	1.79	19.0	0			.48							20.0				
S-D2-24-74	24	167.3-178.2	Shale		Wet 6.5CM	39	9.0		7.8						.37							7.7				
S-D2-25-74	25	184-198.5	Sand-stone	.05	.05	25	8.8		7.9						.26							3.5				

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH

LAB No.	Boring Number	Depth Inch Feet	Field Text.	Hyd. Cond. 6 Hr. in/hr.	Hyd. Cond. 24 Hr. in/hr.	Set. Vol. ml.	pH @ 25° C 1:5	pH @ 25° C Paste.	pH @ 25° C .01 M CaCl2	Saturation Extract ECe @ 25°C.	Saturation Extract Na. meq./l.	Saturation Extract Ca+Mg. meq./l.	Saturation Extract SAR True	Saturation Extract SAR Ext.	1:5 Ext. EC5 @ 25°C.	1:5 Ext. Ca+Mg meq./l.	1:5 Ext. SAR Est.	G.R. meq./ 100 g	Ca+Mg 1:5 meq./ 100 g.	Tension in Bars 15 % Moisture	Tension in Bars	Tension in Bars	Particle Size Sand %	Particle Size Silt %	Particle Size Clay %	Lab. Text. Class
1	AH-1	0-1	Silt loam	.86	.80	19	7.9		7.3						.07					11.7						
2		1-2	Silt loam	.06	.06	23	8.6		7.7						.10					13.8						
3		2-3.5	F Sandy loam	.19	.22	19	9.2		8.0						.10					5.7						
4		3.5-8	F Sandy loam	.71	.64	17	9.4		8.0						.08					3.0						
5		8-13	Sand-stone	1.2	.91	17	9.3		8.0						.08					3.2						
		13-14	Coal or peat	No Sample Taken																						
6		14-17.5	Shale	.13	.11	32	8.6		7.8						.14					17.3						
7		17.5-19	Sandy-shale	.14	.11	23	8.7		7.7						.10					8.8						
8		19-20	Shale	.14	.13	22	8.9		7.7						.12					7.9						
135	AH-2	0-0.8	F Sandy loam	.55	.50	20	7.6								.03					6.6						
136		0.8-3	F Sandy loam	.45	.42	18	8.5								.06					4.8						
137		3-5	Sand-stone	.69	.67	18	8.9								.05					4.2						
9	AH-3	0-2	Clay	.10	.07	24	8.3		7.6						.09					21.0						
10		2-3	Clay loam	.31	.36	22	8.9		7.8						.10					14.7						
11		3-5	Shale	.09	.11	32	8.4		8.1	10.3	23.6	159.6	2.7		2.80					31.6						
12		5-6	Sandy-shale	.23	.25	21	9.1		8.1						.30					7.2						
13		6-8.7	Shale	.08	.09	29	8.9		8.0						.36					21.1						
14		8.7-10	Coal	1.83	1.18	33	8.4		8.0	4.6	15.7	46.9	3.2		.85					44.1						
15		10-14	Shale	.10	.10	33	8.2		7.7						.41					24.0						
16		14-18	organic shale	1.51	.86	29	4.4		4.1						.28					--						
17		18-20	Mud-stone	.06	.07	30	7.3		6.6						.18					18.7						

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH

LAB No.	Boring Number	Depth Inch Feet	Field Text.	Hyd. Cond.		Set.	pH @ 25° C			Saturation Extract					1:5 Ext.			G.R.	Ca+Mg	Tension in Bars			Particle Size			
				6 Hr.	24 Hr.	Vol.				ECe @	Na.	Ca+Mg.	SAR		EC5 @	Ca+Mg.	SAR	meq./	1:5 meq./	15			Sand	Silt	Clay	Lab. Text. Class
				in/hr.	in/hr.	ml.	1:5	Paste.	.01 M CaCl2	25°C.	meq./l.	meq./l.	True	Ext.	25°C.	meq./l.	Est.	100 g.	100 g.	% Moisture			%	%	%	
138	AH-4	0-1.8	Clay loam	.29	.21	21	8.1								.03					11.0						
139		1.8-3	Shale	.18	.18	26	8.9								.09					10.1						
140		3-4	Sand-stone	.47	.47	19	9.1								.06					5.6						
141		4-6	Shale	.21	.18	28	8.4			5.57	16.8	68.2	2.9		.86					26.4						
142		6-9	Shale	.05	.05	29	8.7								.35					17.1						
143	AH-5	0-1	Clay loam	.47	.34	24	8.3								.09					10.3						
144		1-3	Clay	.37	.45	26	8.1			4.36	6.0	62.2	1.1		1.45											
145		3-5	Clay	.15	.15	27	8.7			4.83	25.8	38.8	5.9		.52											
146		5-7	Shale	.10	.07	28	8.6			7.10	34.0	57.0	6.4		.84											
147		7-11.5	Sand-stone	.37	.34	20	8.7								.43											
148	AH-6	0-1	Clay	.45	.34	24	8.4								.09											
149		1-3	Sand-stone	.39	.42	22	8.7								.08											
150		3-5	Shale	.26	.29	29	8.9								.15											
151		5-7.5	Shale	.32	.29	27	8.3			5.10	14.0	56.2	2.6		.88											
152		7.5-9	Silt stone	.10	.10	21	8.0			6.49	16.0	75.2	2.6		1.58											
153		9-10	Organic shale	.07	.05	25	7.6			6.32	15.8	77.6	2.5		2.13											
154		10-15	Shale	.20	.20	26	7.2			5.13	11.6	65.0	2.0		.72											

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH

LAB. No.	Boring Number	Depth Inch Feet	Field Text.	Hyd. Cond.		Set.	pH @ 25° C			Saturation Extract					1:5 Ext.			G.R.	Ca+Mg	Tension in Bars			Particle Size			
				6 Hr. in/hr.	24 Hr. in/hr.	Vol. ml.	1:5	Paste.	.01 M CaCl2	ECe @ 25°C.	Na. meq./l.	Ca+Mg meq./l.	SAR True	SAR Ext.	EC5 @ 25°C.	Ca+Mg meq./l.	SAR Est.	meq./ 100 g	1:5 meq./ 100 g.	15 % Moisture			Sand %	Silt %	Clay %	Lab. Text. Class
155	AH-7	0-1	Clay	.07	.05	27	8.1								.15											
156		1-2	Clay	.11	.13	30	8.4			8.75	44.0	89.8	6.6		1.44											
157		2-3	Clay	.26	.26	26	7.0			9.51	34.4	94.6	5.0		3.27											
158		3-4	Mud-stone	.05	.05	24	8.6			5.44	40.4	31.6	10.0		.70											
159		4-5	Shale	0	.03	32	8.7			7.54	29.8	49.8	6.0		1.09											
160		5-9.5	Sand-stone	1.24	1.09	20	8.9								.44											
161		9.5-10	Sand-stone	.18	.21	24	8.8								.38											
162		10-12.5	Sand-stone	.42	.45	21	9.0								.30											
163	AH-8	0-1	Clay loam	.21	.16	22	8.0								.05											
164		1-2	S Clay loam	.54	.61	23	7.7								.04											
165		2-3	Clay	.32	.32	24	7.8								.04											
166		3.10	Sand-stone	1.50	1.24	19	8.9								.05											
167	AH-9	0-2	Clay	.11	.08	28	8.8								.18											
168		2-3	Clay	.08	.05	27	7.0			5.33	40.0	28.6	10.6		.75											
169		3-4.5	Clay loam	.05	.07	27	9.2			4.76	38.0	19.8	12.1		.52											
170	AH-10	0-2	Clay	.20	.12	23	8.4								.10											
171		2-5	Shale	.10	.07	31	8.9								.30											
172		5-7	Organic shale	.11	.11	29	8.5			7.48	36.0	69.6	6.1		1.09											
173		7-8	Mud-stone	.11	.11	24	8.2			8.10	35.0	83.2	5.4		1.56											

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH

LAB No.	Boring Number	Depth	Field	Hyd Cond.		Set.	pH			Saturation Extract					1:5 Ext.			G.R.	Ca+Mg	Tension in Bars			Particle Size			Lab. Text. Class
		Inch	Text.	6 Hr.	24 Hr.	Vol.	@ 25° C			ECe @	Na.	Ca+Mg	SAR		EC_5 @	Ca+Mg	SAR	meq./	1:5 meq./	15			Sand	Silt	Clay	
		Feet		in/hr.	in/hr.	ml.	1:5	Paste.	.01 M Ca Cl2	25°C.	meq./l.	meq./l.	True	Ext.	25°C.	meq./l.	Est.	100 g.	100 g.	% Moisture			%	%	%	
74	AH-11	0-1	S Clay loam	.32	.29	21	7.6		7.3						.09					10.4						
75		1-3	Clay	.29	.29	23	7.5		7.2						.06					12.2						
76		3-4	Shale	.11	.11	32	7.8		7.6						.14					19.8						
77		4-6	Shale	.17	.17	23	8.2		7.7						.12					12.5						
78		6-7	Shale	.79	.63	20	8.3		7.9						.12					8.9						
79		7-9.5	Shale	.32	.32	22	8.4		7.4						.17					12.4						
80		9.5-12	Mud-stone	.19	.19	23	8.4		8.0						.15					8.9						
81		12-16.5	Shale	.12	.11	23	8.4		8.0						.22					12.8						
82		16.5-19	organic shale	.03	.03	34	8.1		7.8	5.16	21.6	50.6	4.3		.59					25.6						
174	AH-12	0-1	Loam	.20	.17	22	7.3								.06											
175		1-3.5	Clay	.10	.07	22	7.2								.04											
176		3.5-4.5	Sand-stone	.15	.12	20	7.8								.09											
116	AH-13	0-1	Clay loam	.18	.11	24	8.2		7.5						.11					18.6						
117		1-2	Clay	.53	.53	24	8.4		7.8						.05					17.9						
118		2-3	Clay	.23	.29	23	8.6		7.9						.08					15.6						
119		3-4	Clay loam	.32	.34	23	8.9		8.1						.08					9.7						
120		4-8	Sand-stone	.74	.68	18	8.9		8.0						.07					4.8						
121		8-9	Organic shale	.07	.07	29	8.5		7.8						.18					20.1						
122		9-10	Shale	.05	.05	28	8.7		7.9						.10					17.2						
123		10-11.5	Shale	.13	.16	24	8.7		7.8						.09					13.6						
124		11.5-15	Shale	.08	.08	27	8.8		7.9						.10					17.1						
125		15-17	Shale	.11	.13	22	8.8		8.0						.10					10.3						

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH

LAB. No.	Boring Number	Depth Inch Feet	Field Text.	Hyd. Cond.		Set. Vol. ml.	pH @ 25° C			Saturation Extract					1:5 Ext.			G.R. meq./ 100 g	Ca+Mg 1:5 meq./ 100 g.	Tension in Bars			Particle Size			
				6 Hr. in/hr.	24Hr. in/hr.		1:5	Paste.	.01 M CaCl2	EC_e @ 25°C.	Na. meq./l.	Ca+Mg. meq./l.	SAR True	SAR Ext.	EC_5 @ 25°C.	Ca+Mg. meq./l.	SAR Est.			% Moisture			Sand %	Silt %	Clay %	Lab. Text. Class
177	AH-14	0-3.5	Clay	.18	.18	28	8.0			7.42	36.0	68.2	6.2		1.21											
178		3.5-7	Clay loam	.17	.17	25	8.4			8.38	40.0	67.4	6.9		.91											
179		7-9	Shale	.15	.17	28	9.1								.18											
180	AH-15	0-1	Clay	.40	.30	23	8.1								.05											
181		1-2.5	Clay	.17	.20	28	8.8								.11											
No sample		2.5-3	Mud stone			No Sample Taken																				
182		3-5	Shale	.07	.07	30	8.9								.21											
183		5-7	Sand-stone	.20	.20	22	9.0								.12											
184	AH-16	0-1	Clay loam	.16	.11	27	8.6								.11											
185		1-2	Clay	.24	.26	26	8.7								.10											
186		2-4.5	Shale	.13	.16	33	8.9								.21											
		4.5-5	Mud-stone			No Sample Taken																				
187		5-9	Shale	.03	.03	32	8.5								.42											
188		9-10	Mud-stone	.07	.05	23	8.8								.18											
189		10-11	Organic shale	.26	.21	29	8.6								.20											
190		11-17.5	Shale	.02	.02	32	8.8								.12											
		17.5-18	Mud-stone			No Sample Taken																				
191		18-19	Shale	.05	.05	33	8.7								.11											
192		19-21	Organic shale	.05	.04	32	8.5								.10											
193		21-23	Shale	.12	.10	28	8.5								.10											

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH

LAB. No.	Baring Number	Depth Inch Feet	Field Text.	Hyd. Cond. 6 Hr.		Set. Vol.	pH @ 25° C			Saturation Extract					1:5 Ext.			G.R.	Ca+Mg 1:5	Tension in Bars			Particle Size			
				6 Hr. in/hr.	24 Hr. in/hr.	ml.	1:5	Paste.	.01 M CaCl2	ECe @ 25°C.	Na. meq./l.	Ca+Mg. meq./l.	SAR True	SAR Ext.	EC5 @ 25°C.	Ca+Mg meq./l.	SAR Est.	meq./ 100 g.	meq./ 100 g.	15 % Moisture			Sand %	Silt %	Clay %	Lab. Text. Class
194	AH-17	0-1	Clay loam	.34	.24	23	7.7								.05											
195		1-2	Clay	.24	.26	24	8.0								.04											
196		2-3	Clay	.13	.16	24	8.8								.12											
197		3-7	Mud-stone	.12	.12	23	8.2			4.22	10.0	50.6	2.0		.63											
198		7-7.8	Sand-stone	.29	.29	21	8.4								.22											
199	AH-18	0-1	Clay	.08	.08	23	7.8								.06											
200		1-3	Shale	.05	.03	27	8.3			4.03	18.4	38.8	4.2		.45											
201		3-7	Shale	0	0	29	8.4			4.73	24.0	26.2	6.6		.46											
202		7-10	Mud-stone	.07	.05	25	8.8								.23											
203		10-11	Sand-stone	.10	.10	23	8.8								.14											
126	AH-19	0-2	Clay	.05	.02	25	8.4		7.7						.12					19.4						
127		2-4	Shale	.06	.07	24	9.0		8.2						.17					13.2						
128		4-8	Mud-stone	.07	.07	24	8.7		8.0						.33					10.9						
129		8-9	Organic shale	.18	.18	36	7.3		6.6	4.38	16.0	44.4	3.4		.73					34.9						
130		9-10	Coal	1 drop	1 drop	40	5.9		5.2						.39					47.0						
131		10-11	Organic shale	.08	.05	34	7.5		7.2						.16					23.3						
132		11-14	Silt stone	.01	.01	28	7.9		7.4						.08					15.8						
133		14-15	Shale	.02	.02	28	8.1		7.7						.08					14.7						
134		15-16	Silt stone	.05	.07	21	8.4		7.7						.10					13.6						
204	AH-20	0-1	Clay loam	.07	.07	22	7.5								.04											
205		1-2	Clay	--	.01	29	8.6								.12											
206		2-7	Shale	.10	.07	29	8.6			7.66	44.2	59.4	8.1		.10											
207		7-9.5	Sand-stone	.07	.05	24	9.0								.17											

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH

LAB. No.	Boring Number	Depth Inch Feet	Field Text.	Hyd. Cond.		Set. Vol.	pH @ 25° C			Soturation Extroct					1:5 Ext.			G.R.	Ca+Mg	Tension in Bars			Porticle Size			
				6 Hr.	24 Hr.					ECe @	Na.	Co+Mg	SAR		EC5 @	Co+Mg	SAR	meq./	1:5 meq./	15			Sond	Silt	Cloy	Lab. Text. Class
				in/hr.	in/hr.	ml.	1:5	Poste.	.01 M CaCl2	25°C.	meq./l.	meq./l.	True	Ext.	25°C.	meq./l.	Est.	100 g.	100 g.	% Maisture			%	%	%	
208	AH-21	0-1	Clay loam	.02	.01	25	8.0								.07											
209		1-2	Clay	.13	.16	28	8.2								.15											
210		2.3	Clay	.07	.07	27	8.3			6.58	31.8	67.4	5.5		.46											
211		3.6	Sand-stone	.12	.12	22	8.7								.06											
212	AH-22	0-1	Clay loam	.05	.05	22	8.0								.05											
213		1-2	Clay	.12	.12	24	8.3								.07											
214		2-3	Organic shale	.13	.13	24	8.3								.12											
215		3-5	Shale	.07	.06	26	8.4			5.00	8.0	73.6	1.3		.84											
216		5-6.5	Sand-stone	.07	.05	23	8.6			6.67	24.0	76.4	3.9		.53											
No sample		6.5-7	Mud-stone			No Sample Taken																				
217		7-9	Sand-stone	.05	.05	23	8.8								.37											
218	AH-23	0-2	Silt stone	.09	.07	24	8.8								.10											
219		2-3	Clay	.11	.13	30	8.9								.10											
220		3-5	Clay	.07	.07	27	8.9								.11											
221		5-7	Shale	.26	.24	26	9.1								.12											
222		7-10	Coal	.26	.21	38	8.6			1.43	9.0	22.6	2.7		.55											
223		10-13.5	Shale	.08	.08	29	8.9								.19											

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH

LAB No.	Boring Number	Depth Inch Feet	Field Text.	Hyd. Cond. 6 Hr. in/hr.	Hyd. Cond. 24 Hr. in/hr.	Set. Vol. ml.	pH @ 25° C 1:5	pH @ 25° C Paste.	pH @ 25° C .01 M Ca Cl2	Saturation Extract ECe @ 25°C.	Saturation Extract Na. meq./l.	Saturation Extract Ca+Mg. meq./l.	Saturation Extract SAR True	Saturation Extract SAR Ext.	1:5 Ext. EC5 @ 25°C.	1:5 Ext. Ca+Mg. meq./l.	1:5 Ext. SAR Est.	G.R. meq./ 100 g.	Ca+Mg 1:5 meq./ 100 g.	Tension in Bars 15 % Moisture	Tension in Bars	Tension in Bars	Particle Size Sand %	Particle Size Silt %	Particle Size Clay %	Lab. Text. Class
18	AH-24	0-3	Clay	.15	.15	30	9.0								.19					11.6						
19		3-4	Mud-stone	.20	.22	25	9.0								.31					18.3						
20		4-6	Shale	.12	.12	29	8.8			8.24	26.0	106.2	3.6		1.54					13.5						
21		6-7	Mud-stone	.12	.13	31	8.9			6.20	23.8	71.2	4.0		.83					11.8						
22		7-11	Shale	.07	.07	29	8.7			5.94	16.0	69.0	2.7		.75					16.8						
23		11-13	Mud-stone	.12	.11	33	8.6			5.21	10.4	61.0	1.9		.69					15.2						
24		13-14	Mud-stone	.10	.10	31	8.6			5.24	9.8	65.0	1.7		.65					19.0						
25		14-15	Shale	.08	.08	31	8.6			4.12	6.1	49.3	1.2		.53					17.3						
26		15-16	Mud-stone	.05	.03	31	8.6								.42					12.5						
224	AH-25	0-1	Loam	.05	.07	21	7.9								.06											
225		1-2.4	Clay loam	.05	.02	24	7.6								.04											
226		2.4-4	Sand-stone	.07	.07	23	8.0								.06											
227	AH-26	0-1	Loam	.12	.10	23	7.9								.07											
228		1-5	Clay loam	.05	.05	25	8.1								.07											
229		5-9	Clay	.07	.05	25	8.0								.09											
230		9-13	S Clay loam	.10	.07	30	8.4								.12											
231		13-17	Clay	.11	.13	24	8.6								.09											
232		17-18	Sand-stone	.68	.63	21	8.6								.07											
233	AH-27	0-3	Clay	.07	.05	30	8.6								.13											
234		3-5	Shale	0	.02	30	8.3			7.54	38.4	78.4	6.1		.77											
235		5-7	Sand-stone	.05	.10	23	8.8								.28											

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH

LAB No.	Boring Number	Depth Inch Feet	Field Text.	Hyd. Cond. 6 Hr.	Hyd. Cond. 24 Hr.	Set. Vol.	pH @ 25° C			Saturation Extract					1:5 Ext.			G.R.	Ca+Mg 1:5	Tension in Bars			Particle Size			Lab. Text. Class
				in/hr.	in/hr.	ml.	1:5	Paste.	.01 M CaCl2	ECe @ 25°C.	Na. meq./l.	Ca+Mg. meq./l.	SAR True	SAR Ext.	EC5 @ 25°C.	Ca+Mg meq./l.	SAR Est.	meq./ 100 g.	meq./ 100 g.	15 % Moisture			Sand %	Silt %	Clay %	
236	AH-28	0-1	Clay loam	.05	.05	22	8.0								.05											
237		1-3.5	Clay	.08	.05	23	7.9								.04											
		3.5-4	Shale	No Sample Taken																						
238		4-7	Shale	.05	.05	25	8.5								.25											
239		7-9.5	Sand-stone	.07	.10	22	8.4			6.90	20.4	77.6	3.3		.57											
240		9.5-10.7	Shale	.05	.05	27	8.6			7.20	27.0	79.2	4.3		.72											
241		10.7-12	Shale	.05	.05	26	8.7			5.70	21.8	66.2	3.8		.53											
242		12-15	Shale	.03	.03	28	8.2			7.48	23.0	109.0	3.1		1.54											
243		15-16	Organic shale	.02	.02	30	8.2			6.53	18.4	106.2	2.5		1.15											
244		16-18	Shale	.06	.05	28	8.4								.39											
245		18-19.6	Organic shale	.05	.05	34	8.4								.39											
246		19.6-21	Mud-stone	.06	.05	24	8.2								.25											
247	AH-29	0-1	Clay loam	.11	.09	24	8.2								.08											
248		1-2	S Clay loam	.14	.12	23	8.7								.08											
249		2-3	S Clay loam	.07	.07	24	8.7								.08											
		3-3.5	Shale	No Sample taken																						
250		3.5-5	Shale	.07	.07	25	8.4								.11											
251		5-7	Mud-stone	.12	.12	22	9.1								.08											
252		7-8	Mud-stone	.07	.07	25	9.0								.10											
253		8-10	Shale	.05	.05	32	9.0								.14											
254		10-11	Shale	.07	.07	27	9.1								.12											
255		11-19	Shale	.05	.05	25	8.8								.17											
256		19-22	Shale	.18	.12	30	8.1								.10											
257		22-25	Shale	.05	.05	28	8.4								.12											

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH

LAB. No.	Boring Number	Depth Inch Feet	Field Text.	Hyd. Cond.		Set. Vol.	pH @ 25° C			Saturation Extract					1:5 Ext.			G.R.	Ca+Mg 1:5	Tension in Bars			Particle Size			
				6 Hr.	24 Hr.					ECe @ 25°C.	Na. meq./l.	Ca+Mg meq./l.	SAR		EC5 @ 25°C.	Ca+Mg meq./l.	SAR Est.	meq./ 100 g.	meq./ 100 g.	15			Sand	Silt	Clay	Lab. Text. Class
				in/hr.	in/hr.	ml.	1:5	Paste.	.01 M CaCl2				True	Ext.						% Moisture			%	%	%	
258	AH-30	0-1	Clay	.16	.11	24	8.5								.10											
259		1-3	Clay	.05	.05	27	8.7								.26											
260		3-4	Shale	0	.01	31	8.0			8.03	34.8	86.4	5.3		2.57											
261		4-5	Organic shale	.01	.03	31	7.9			7.77	34.0	82.4	5.3		2.06											
262		5-8	Shale	.03	.03	25	8.3			6.53	24.0	69.6	4.1		.58											

APPENDIX B

LABORATORY GREENHOUSE STUDY

TAYLOR CREEK STUDY SITE

Part of Contract 14-06-0-7554
U.S. Bureau of Reclamation

Prepared by
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May 1975

LABORATORY GREENHOUSE STUDY

Introduction

In the past, surface mining for coal generally resulted in burying of the soil and then attempts were made to revegetate the spoil. The spoil left exposed was usually from the stratum directly overlying the coal seam and often was not a suitable plant growth medium.

It is visualized that in future surface mining operations, the soil will be conserved and replaced. On some sites, however, the soil will be thin or less suitable as a plant growth medium than spoil generated from certain overburden strata. The objective of this study was to evaluate the suitability of overburden as a plant growth media.

This greenhouse study was carried out in cooperation with and is a portion of a larger study conducted by the Bureau of Reclamation in coring and characterizing overburden on four potential Federal coal lease sites.

The help of Gary Browning, CSU undergraduate, in carrying out the greenhouse work is greatly appreciated. Special thanks also go to the personnel of the U.S. Bureau of Reclamation for their help.

Methods

Field capacity

The initial task in the greenhouse study was to determine the field capacity of the overburden samples. The equipment used to determine field capacity was plastic tubes 1 3/4 inches in diameter, plastic cups, and plastic sheets. The cups were weighed to the nearest 0.1 gram and the weights recorded. Three hundred grams of each overburden sample were weighed and placed in the plastic cylinders which had been sealed at the bottom by a plastic sheet. The samples were then packed by tapping the side of the cylinder. Fifteen milliliters of water were then added (5 percent of the overburden sample by weight), and the top was sealed with plastic. After 24 hours the bottom plastic was removed and the dry overburden fell into the cup, leaving the moist overburden in the cylinder. The weight of the cup plus dry overburden was taken and the field capacity (FC) calculated by the following equation:

$$\text{FC percent} = \frac{15\text{g}H_2O}{\text{weight of moist overburden} - 15\text{g}H_2O} \times 100$$

This field capacity percentage was the basis for the amount of water each pot received daily.

Fertilizer treatments

Two thousand grams of overburden were weighed into each pot except where the bulk density was low or insufficient sample was available. Each pot was fertilized with 100 p.p.m. nitrogen as reagent grade $Ca(NO3)_2$ and 80 p.p.m. phosphorus as reagent grade $Ca(H_2PO_4)_2\ H_2O$. The reagents were added in solution as 10 and 50 milliliter aliquots, respectively, then mixed into the soils and overburden.

Seeding and growth

Western wheatgrass (Agropyron smithii var. arriba) was the test species. This species was chosen because it is one of the most abundant native grasses in the western United States and will probably be used in revegetation programs. At the time of seeding, approximately 250 grams of overburden were removed from each pot. Then water was added to each pot to bring them to field capacity. Thirty-five seeds were placed in each pot and the removed overburden placed on the seeds. All pots were then covered with paper to retard evaporation and allow the water to move to the surface by capillary rise. The pots were checked daily and water added as needed to keep the surface moist. Germination was checked daily and upon germination, each pot was uncovered and the date recorded. The date when ten plants had emerged and the severity of salt crusting were also recorded. After germination, all pots were weighed daily, and deionized water was added to bring the soil to field capacity. Maximum water use generally was about 25 percent of field capacity per day.

When most of the plants, in all pots, reached a height of about 10 centimeters, the number of plants in each pot was recorded and each pot was thinned to 16 plants.

The plants were grown for 53 days, from seeding, in the first greenhouse experiment (October 5 to November 27, 1974) and for 52 days in the second experiment (January 26 to March 19, 1975).

A highly productive loam soil (A^1 horizon Platner series) was included in both experiments as a standard soil. The surface sample from Utah (K(1)1-74) and the soil profile sample (W-198) from Montana were also included in both greenhouse experiments as standards. Due to a lack of the bulk standard sample from Colorado, some overburden samples used in the first experiment were reseeded and used in the second greenhouse experiments as standards. The samples reused from Colorado were S-D1-1-74 (2 pots) and S-1-control (1 pot).

In Table 1, samples used in both greenhouse experiments are shown by a designation of Fall "74" for the first experiment and Winter "75" for the second experiment.

Harvesting

The plants were clipped at a height of 2 centimeters above the surface, washed in 0.05 normal HCl, and rinsed in distilled water. The plants were dried in a forced air oven at 70° C. for 24 hours and then weighed to the nearest 0.01 gram.

Observations taken at the time of harvest included: (1) the presence of rhizomes, (2) the amount of black leaf tips, (3) the degree of soil surface cracking, (4) the amount of salt crusting, and (5) the average plant height.

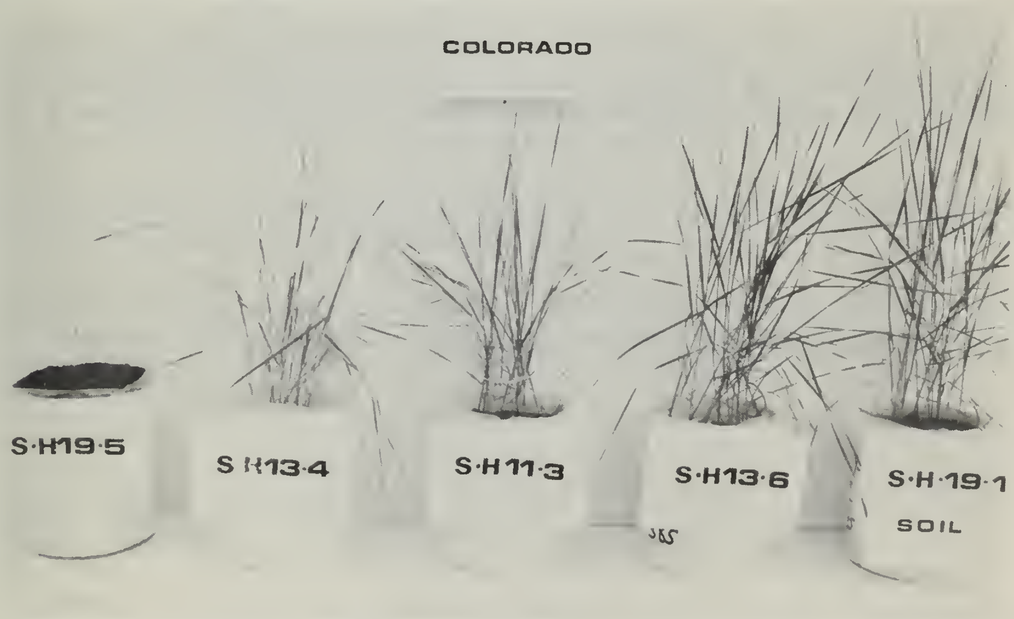
Additional data

Textural analysis was run on the samples in the first greenhouse experiment to determine if the alternate wetting and drying cycles associated with watering would weather the samples and thus change the texture. It was found that there were no significant differences in texture before and after cropping.

Blackening of the leaf tips was noted in both greenhouse experiments on various samples. This blackening of leaf tips might be boron toxicity and should be investigated further.

Results and Discussion

Large differences in western wheatgrass growth are evident on various overburden samples as shown below. For purposes of this discussion, yields of less than 1 gram will be considered low, yields of 1 to 2 grams medium, and above 2 grams high.



Range in growth on samples from Taylor Creek site in Colorado.

Yields on the overburden samples from the Taylor Creek site in northwestern Colorado ranged from good to poor with yields on the 0- to 30-foot samples generally greater than yields on samples deeper than 30 feet (Figure 1, Table 1). The Taylor Creek samples (Mesa Verde Formation) were mainly coarse-textured materials with a low water-holding capacity. As a general rule, those samples which had a field capacity of 14 percent or more produced the highest yields.

Yields on the Colorado soil profile samples were highly variable with the surface samples generally yielding the most (Figure 1). The yields on soils also depended upon the texture of the sample with the finer-textured materials yielding more than the coarse textured.

The degree of salt crusting and surface cracking of the overburden was given a numerical designation as follows:

0 - None
1 - Very slight
2 - Slight
3 - Moderate
4 - Extreme

Blackened leaf tips were observed and frequency of occurrence, within pots, was recorded as follows:

0 - no plants with black leaf tips
1 - 1- 4 " " " " "
2 - 5- 8 " " " " "
3 - 9-12 " " " " "
4 - 13-16 " " " " "

These blackened leaf tips (5 to 10 mm) changed to a brown color after 1 to 2 weeks. Although the leaf tips died back, there was no evidence of overall yield reduction of plants so affected.

Bulk density of the overburden samples was calculated; this information is not recorded but is available.

Roman numerals I and II in Table 1 refer to replications. Duplicate pots were run on all soil and overburden samples for which there was adequate soil material.

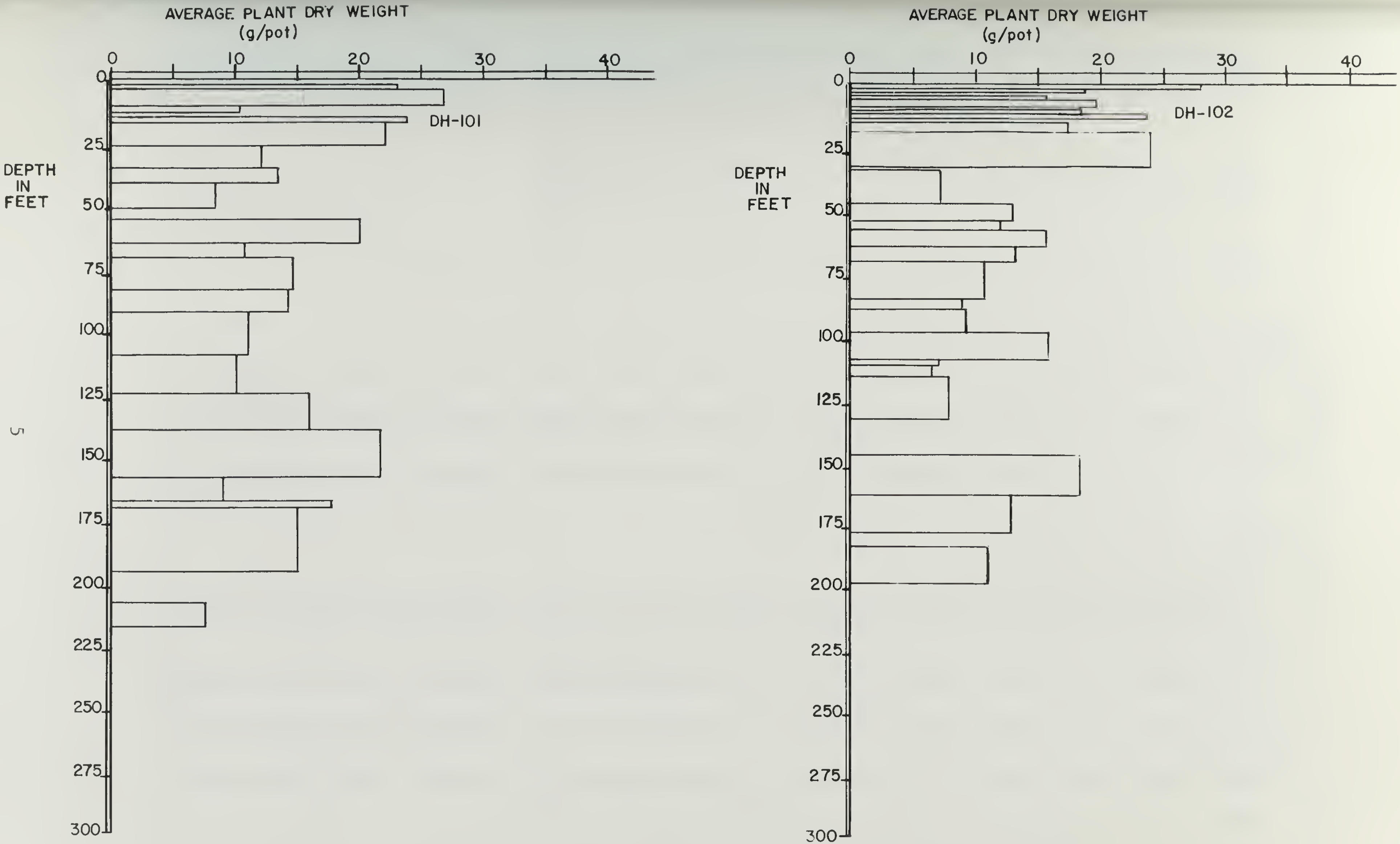


Figure 1: Yields of western wheatgrass grown on overburden from Taylor Creek in Colorado.

Table 1
Greenhouse data for Colorado site

Sheet 1 of 2

Sample number	Depth (feet)	Pot weight (Kg)	Germination: Days after seeding for ten plants to emerge		Germination: Number of seeds germinated		Salt crust at germination	Salt crust at harvest	Harvest: Plant dry weight (gm)		Harvest: Average plant height (cm)		Black leaf tips	Soil surface cracks	Field capacity (percent)
			I	II	I	II			I	II	I	II			
S-H1- 1-74	0 - 1	2	5	5	33	33			2.27	2.22	35	29	2		14.1
S-H1- 2-74	1 - 2	2	7	7	32	35			1.75	1.93	34	31			12.1
S-H1- 3-74	2 - 3.5	2	7	7	31	31			1.05	.86	25	26			8.6
S-H1- 4-74	3.5- 8	2	6	6	32	228			.85	1.09	24	27			7.3
S-H1- 5-74	8 - 13	2	6	6	33	32			.87	.88	26	22			7.4
S-H1- 6-74	14 - 17.5	2	6	6	34	33			1.28	1.62	28	29	3	2	13.4
S-H1- 7-74	17.5- 19	2	6	6	30	29			1.55	1.83	30	31	2		10.8
S-H1- 8-74	19 - 20	2	6	6	32	35			2.60	1.77	38	33	1		12.1
S-H3- 1-74	0 - 2	2	5	5	28	28			2.18	2.34	34	36			15.1
S-H3- 2-74	2 - 3	2	6	6	31	21			1.59	1.18	30	25	1	2	12.8
S-H3- 3-74	3 - 5	2	7	7	32	30	3		.50	.41	19	18	3		15.1
S-H3- 4-74	5 - 6	2	6	6	34	31			1.46	1.41	30	29	2	1	10.4
S-H3- 5-74	6 - 8.7	2	6	6	32	31			.79	.76	25	22	3	1	12.9
S-H3- 6-74	8.7- 10	1.5	6	6	34	33			.53	.48	19	20	4		18.7
S-H3- 7-74	10 - 14	2	6	6	29	32	2		.74	1.48	33	31	3	1	15.6
S-H3- 8-74	14 - 18	1.5	9	10	33	28	2		.18	.20	16	9			7.2
S-H3- 9-74	18 - 20	2	6	6	20	35	2		1.65	1.97	32	29	2	1	12.3
S-H24-1-74	0 - 3	2	6	6	34	32			1.39	1.56	30	27		2	14.1
S-H24-2-74	3 - 4	2	7	7	31	32			.88	.90	27	29			10.3
S-H24-3-74	4 - 6	2	7	7	29	32			1.02	.88	25	24			12.7
S-H24-4-74	6 - 7	2	6	6	27	28			1.00	1.06	27	27			12.9
S-H24-5-74	7 - 11	2	6	6	34	32			1.55	1.57	30	26	2		11.3
S-H24-6-74	11 - 13	2	7	7	33	30			1.37	1.22	27	27	1		12.4
S-H24-7-74	13 - 14	2	6	6	33	32	1		.92	.96	25	25	1	1	10.0
S-H24-8-74	14 - 15	2	7	7	31	32			1.04	1.19	27	27	2	1	11.5
S-H24-9-74	15 - 16	2	8	8	22	16			1.53	1.21	31	26	3	2	11.1
S-D1- 1-74	0 - 1	2	6	6	35	32			2.22	2.38	34	35	1	2	13.2
S-D1- 2-74	1 - 2	2	6	6	32	33			1.43	1.74	30	30			13.7
S-D1- 3-74	2 - 8	2	6	6	34	34	2	2	2.71	2.65	38	39	2		16.9
S-D1- 4-74	8 - 12	2	6	6	33	33	2	1	.94	1.10	28	28	1		10.5
S-D1- 5-74	13 - 14	2					insufficient data								
S-D1- 6-74	14 - 16	2	5	5	34	33			2.39	2.38	37	37	3	1	13.2
S-D1- 7-74	16 - 25.8	2	6	6	30	35			2.14	2.25	35	37	2		8.4
S-D1- 8-74	25.8- 34.5	2	6	6	32	31			1.30	1.14	30	30			10.2
S-D1- 9-74	34.5- 41.1	2	6	6	33	32			1.25	1.47	31	30			9.9
S-D1-10-74	41.5- 51.5	2	5	5	29	28			.92	.75	30	28			8.1
S-D1-11-74	55.4- 64.1	2	6	6	33	31			1.83	2.13	36	40			10.2
S-D1-12-74	64.1- 70.2	2	7	7	25	10			1.44	.86	34	31			6.8
S-D1-13-74	70.2- 83.0	2	6	6	34	31			1.57	1.34	32	31			8.9
S-D1-14-74	83.0- 92.5	2	7	7	11	22			1.67	1.19	32	35	4		6.1
S-D1-15-74	92.5-110.2	2	6	6	29	31			1.04	1.17	31	28			9.9
S-D1-16-74	110.2-124.5	2	6	6	31	33			.95	1.21	30	30			9.9
S-D1-17-74	124.5-138.4	2	6	6	30	334			1.75	1.49	34	32			9.5
S-D1-18-74	138.4-158.7	2	7	7	31	31			2.21	2.12	38	33	1		6.1
S-D1-19-74	158.7-166.5	2	6	6	28	31			.76	1.05	27	28			9.6
S-D1-20-74	166.5-170.8	2	7	7	29	25			1.82	1.73	36	36	1		7.2
S-D1-21-74	170.8-196.5	2	6	6	31	31			1.56	1.45	35	32			10.6
S-D1-22-74	208.4-217.0	2	7	7	28	34			.69	.84	26	24			8.1
S-D2- 1-74	0 - 1	2	5	5	34	34			2.50	3.07	42	39			18.7
S-D2- 2-74	1 - 3	2	5	5	34	34	1		1.90	1.85	31	34			18.4
S-D2- 3-74	3 - 4	2	7	6	35	33	2	2	1.25	1.36	28	31			20.4
S-D2- 4-74	4 - 4.8	2	6	6	30	31	2	2	1.61	1.53	27	32			18.1
S-D2- 5-74	4.8- 8	2	7	6	30	30	1		1.98	1.97	33	32			18.2
S-D2- 6-74	8 - 9	2	6	6	31	35	1	2	1.39	1.66	24	30	1		20.0
S-D2- 7-74	9 - 11	2	5	5	33	31	1		1.92	1.74	33	30			18.1
S-D2- 8-74	11 - 14	2	5	5	32	32	1		2.08	2.59	36	37			13.2
S-D2- 9-74	15.3- 17.6	2	8	*	27	*			1.73	*	29	*		1	11.9
S-D2-10-74	17.6- 33.0	2	5	7	29	32	2	2	2.57	2.20	41	37			15.9
S-D2-11-74	34.3- 47.8	2	8	9	20	25			.69	.75	24	25	3		6.8
S-D2-12-74	47.8- 55.6	2	6	6	35	35		1	1.30	1.32	28	28			14.0
S-D2-13-74	55.6- 58.5	2	8	*	24	*			1.19	*	29	*			7.6
S-D2-14-74	58.5- 64.4	2	6	5	32	32	2	2	1.46	1.66	34	32	2		11.6
S-D2-15-74	64.4- 69.8	2	5	7	31	24			1.29	1.33	29	31	2		9.5
S-D2-16-74	69.8- 85.4	2	7	8	21	20			1.01	1.10	29	29	4		6.6
S-D2-17-74	85.4- 88.2	2	7	7	24	22			.75	1.02	27	25			9.2
S-D2-18-74	88.2- 97.0	2	7	14	20	14			.97	.87	26	27			7.1
S-D2-19-74	97.0-109.2	2	7	7	28	28			1.58	1.57	34	32			10.4
S-D2-20-74	109.2-111.7	2	10	10	26	18			.71	.72	24	25	3		6.3
S-D2-21-74	111.7-116.6	2	10	12	31	25			.64	.65	23	24			10.9
S-D2-22-74	116.6-133.0	2	6	7	26	31			.67	.87	24	26			12.7
S-D2-23-74	147.6-167.3	2	7	7	30	29	1		1.92	1.71	32	31			14.3
S-D2-24-74	167.3-178.2	2	7	7	31	32			1.06	1.52	32	32			9.1
S-D2-25-74	184.0-198.5	2	7	7	22	27	1		.86	1.31	30	29	1		8.2

Table 1

Greenhouse data for Colorado site

Sheet 2 of 2

Sample number	Depth (feet)	Pot weight (Kg)	Germination: Days after seeding for ten plants to emerge		Germination: Number of seeds germinated		Salt crust at germination	Salt crust at harvest	Harvest: Plant dry weight (gm)		Harvest: Average plant height (cm)		Black leaf tips	Soil surface cracks	Field capacity (percent)
			I	II	I	II			I	II	I	II			
S-H11-1-74	0 - 1	2	5	5	33	33			2.72	2.55	39	34			15.4
S-H11-2-74	1 - 3	2	5	5	34	32			2.45	2.74	41	36			16.1
S-H11-3-74	3 - 4	2	6	10	32	34			1.21	1.41	30	30			14.7
S-H11-4-74	4 - 6	2	5	5	33	35			2.33	2.83	39	37			16.6
S-H11-5-74	6 - 7	2	10	10	25	23			.92	1.11	26	30	3		13.4
S-H11-6-74	7 - 9.5	2	5	5	35	33	1		1.86	2.35	36	37			16.1
S-H11-7-74	9.5- 12	2	7	5	29	33	1		1.42	1.82	32	35	1		13.1
S-H11-8-74	12 - 16.5	2	6	7	29	33	1		1.93	1.88	31	30			14.3
S-H11-9-74	16.5- 19	2	6	6	32	30	2	2	2.25	2.23	30	29	2	1	23.7
S-H13-1-74	0 - 1	2	6	6	32	32			2.62	2.51	38	32	1		18.3
S-H13-2-74	1 - 2	2	5	*	25	*			2.35	*	38	*	1		19.0
S-H13-3-74	2 - 3	2	7	*	31	*			1.73	*	33	*			17.2
S-H13-4-74	3 - 4	2	12	12	19	21			.81	1.03	29	30			13.1
S-H13-5-74	4 - 8	2	10	7	29	25			1.47	1.46	34	30			9.9
S-H13-6-74	9 - 10	2	5	5	26	31	1		2.52	2.69	33	37			19.1
S-H13-7-74	10 - 11.5	2	6	6	31	30			2.54	2.16	40	34	2		16.3
S-H13-8-74	11.5- 15	2	6	7	32	32		1	2.09	2.26	38	33	1		16.9
S-H13-9-74	15 - 17	2	7	6	31	32			1.66	2.05	38	35	2		12.6
S-H19-1-74	0 - 2	2	5	5	33	33	1		3.34	2.87	43	38			19.6
S-H19-2-74	2 - 4	2	5	5	32	33	1		2.19	2.82	41	41	2		15.7
S-H19-3-74	4 - 8	2	5	5	34	32	1		1.43	1.88	32	31			13.2
S-H19-4-74	8 - 9	1.5	5	*	34	*	2	2	.58	*	23	*			23.1
S-H19-5-74	9 - 10	1.5	13	10	33	28			trace	trace					10.7
S-H19-6-74	10 - 11	2	5	*	27	*	2	2	1.24	*	28	*			20.3
S-H19-7-74	11 - 14	2	5	5	35	33	1		2.61	2.66	39	28			17.9
S-H19-8-74	14 - 15	2	5	5	18	33			3.50	3.61	43	45			20.7
S-H19-9-74	15 - 16	2	7	*	24	*			1.67	*	30	*			14.8
S-1-Control	Surface	2	5	5	33	32			2.46	2.50	37	37			17.8
S-1-Control** Winter 1975	Surface	2	5		32				2.40		32				17.8
S-D1-1-74** Winter 1975	0 - 1	2	6	6	31	35			2.01	2.09	32	36			13.2
S-2-Control	Surface	2	5	5	33	34			2.72	2.61	40	38			18.5
Standard loam Soil fall 1974		2	6	6	33	32			3.28	3.34	41	39			15.2
Standard loam Soil winter 1975		2	6	6	35	33			3.20	2.84	36	36			15.2

* Sample enough for only one pot.

** Pot regrown from fall 1974 greenhouse experiment.

APPENDIX C

WEATHERING TESTS

APPENDIX C

WEATHERING TESTS

This appendix contains the methods and procedures used in conducting weathering tests. Data presented are from selected core samples of the Taylor Creek site only.

As authorized by Form DPC-1, Number 1, dated January 14, 1975, weathering tests were conducted on overburden core samples from four sites: Otter Creek, Mont.; Kanab, Utah; Craig, Colo.; and Hanna, Wyo.

The purpose of these tests was to determine which materials would weather (breakdown) sufficiently to allow for their possible use as topsoil in revegetation of strip-mined areas.

The number of core samples submitted and tested are listed below.

Site	Number of samples submitted	Number of samples tested
Otter Creek, Mont.	20	17
Kanab, Utah	16	8
Craig, Colo.	12	9
Hanna, Wyo.	7	7
Total	55	41

Laboratory Tests

Duplicate specimens from each core depth were selected for either freeze-thaw or wet-dry tests. A freeze-thaw cycle consisted of the following conditions: (1) 8 hours at 75° F., 100 percent relative humidity (wetting/thawing) and (2) 16 hours (64 hours on weekends) at -10° F. (freezing). For the wet-dry tests, one cycle consisted of the following conditions: (1) 8 hours at 75° F., 100 percent relative humidity (wetting) and (2) 16 hours (64 hours on weekends) at 100° F., 10 percent relative humidity (drying).

Where possible, core specimens about 2 inches in diameter by 2 inches high were used. In other cases, several pieces of core samples totaling the approximate same size were used. For testing and handling, the core specimens were placed in 1-pint wax cardboard containers (3 3/8 inches in diameter).

Tests were started on January 30, 1975, and 30 weathering cycles were completed on March 14, 1975. During the test period, the specimens were

visually examined several times a week to determine what changes had occurred. Results of the visual examinations are summarized in Table 1. Abbreviations used in the tables to provide the maximum information in a minimum of space are listed in Table 2. Some of the typical conditions mentioned by abbreviations in Table 2 are illustrated in Figure 1. Also two core samples representing various soil types were photographed before and after the 30 weathering cycles, and this visual record is also shown in Figure 2.

At the completion of the testing, a percent breakdown value (%BD) was determined for a number of the specimens. This value was obtained as follows: $\%BD = \frac{TW - IW}{TW} \times 100$ where TW = total sample weight and IW = weight of original sample remaining intact after testing.

The %BD is listed in the last column under Remarks in Table 1. Generally for samples that exhibited swelling characteristics, no %BD was determined.

Results of the weathering tests indicated that, in general, the freezing-thawing condition caused more weathering or breakdown than wetting-drying. This was evident by both visual examination and gradation analyses conducted on several samples after testing. These gradation analyses are summarized in Table 3.

Based on discussions with Dr. William Berg, Agronomy Department, Colorado State University, concerning soil texture necessary for revegetation, the following laboratory samples at the Craig, Colo., site meet his criterion of a minimum of 30 percent (by weight) passing the No. 10 screen: C-3F; C-4F; C-5F; C-10F.

Summary

Laboratory weathering tests involving both freeze-thaw and wet-dry tests were conducted on 41 overburden core samples from four coal-mined sites. The purpose of these tests was to determine which materials would break down sufficiently to allow for their possible use as topsoil in revegetation of strip-mined areas.

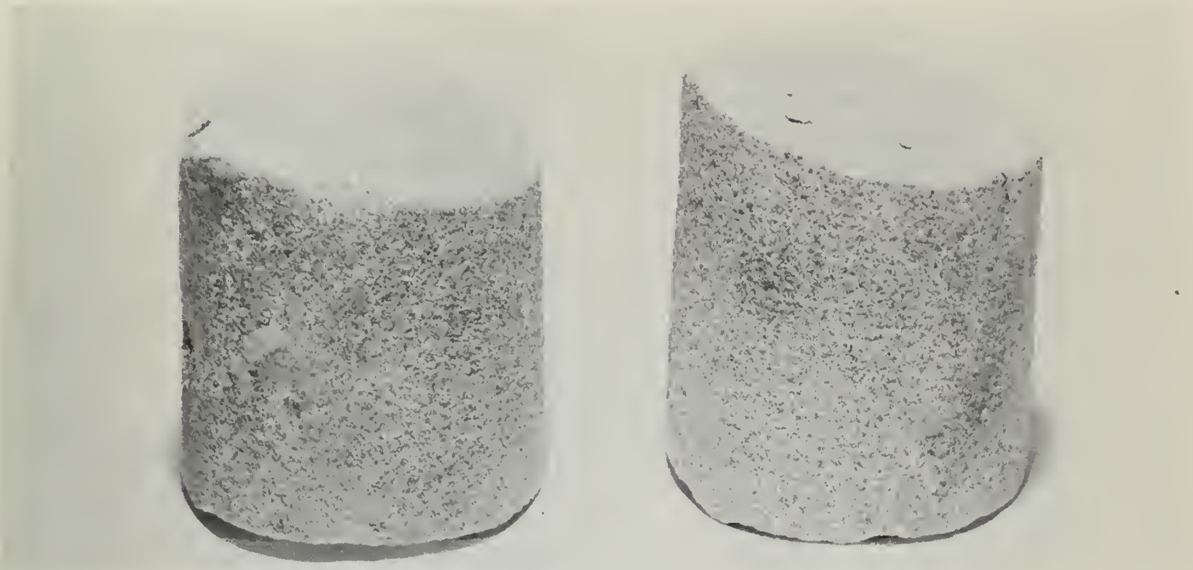
Results of this study indicate that the freeze-thawing condition is more severe than wetting-drying in that it caused more rapid breakdown of the overburden materials. Although no attempt was made in this study to correlate the laboratory weathering to field weathering, it can be expected that freezing-thawing would also be the most severe of the two conditions in the field. The degree of severity, however, would be dependent upon the amount of moisture available at the various sites, especially during snowmelt and runoff when freezing-thawing might occur.

Table 1
Weathering tests
Core samples from Craig, Colo.

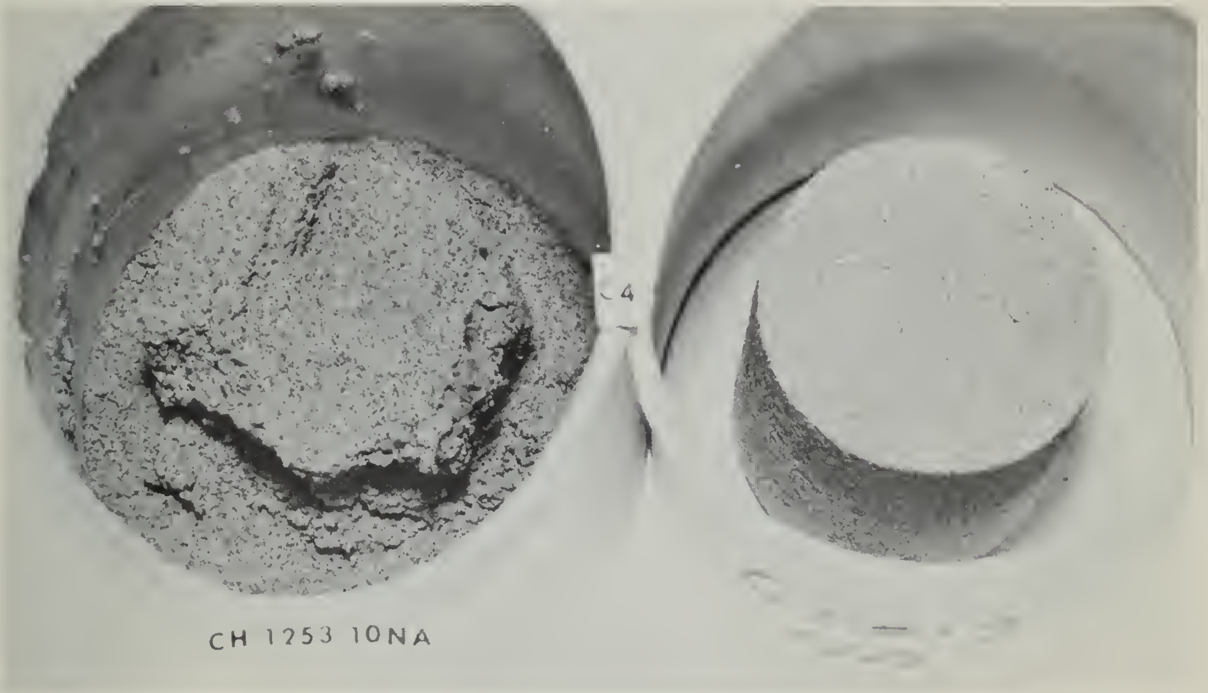
Laboratory sample number	Sample identification	Rock classification	Number of pieces	Remarks		
				Cycles 1-10	Cycles 11-20	Cycles 21-30
C-1F	DH 102	Sandstone	1	NC	S Sc 16 Cy	C 25 Cy: % BD 20.9
C-1W	Depth 14.0' - 15.2'		1	NC	NC	NC; % BD 0
C-2F	DH 102	Mudstone and shale	1	NC	S Sc 16 Cy	Sc 25 Cy; % BD 5
C-2W	Depth 15.2' - 17.5'		1	NC	S Sk 16 Cy	Sk 22 Cy; % BD 26.4
C-3F	DH 102	Mudstone, sandstone, and shale	1	SC 3 Cy; C 3 Cy	S Sat 15 Cy; Sv C 18 Cy	BD 26 Cy; % BD 100
C-3W	Depth 17.5'-33.0'		2	C 6 Cy	Sv C 16 Cy; S Sk 19 Cy	Sk 21 Cy; Sv Sk 30 Cy; % BD 100
C-4F	DH 102	Sandstone	1	NC	S Sc 16 Cy	Sc 22 Cy; Fr 26 Cy; % BD 75.3
C-4W	Depth 34.2' - 47.7'		1	NC	NC	NC; % BD 0
C-5F	DH 102	Shale	2	C 1 Cy; Sv C 8 Cy	Cv 15 Cy	Sv Cv 25 Cy; % BD 100
C-5W	Depth 47.7' - 55.5'		1	NC	C 14 Cy	Cv 21 Cy; Sk 25 Cy; % BD 100
C-7F	DH 102	Shale and mudstone	1	C 2 Cy; Sv C 7 Cy	Sc 15 Cy; Cv 18 Cy	Sv Cv 25 Cy; % BD 72.7
C-7W	Depth 58.4' - 64.3'		1	NC	C 17 Cy	Sk 26 Cy; % BD 29.3
C-9F	DH 102	Sandstone	1	NC	NC	NC; % BD 0
C-9W	Depth 69.7' - 85.3'		1	NC	NC	NC; % BD 0
C-10F	DH 102	Shale	2	C 2 Cy	Sv C 12 Cy; Sk 15 Cy	Cv 22 Cy; % BD 100
C-10W	Depth 85.3' - 88.2'		2	C 5 Cy	Sv C 15 Cy; Cv 18 Cy	Sk 22 Cy; % BD 100
C-12F	DH 102	Mudstone	1	NC	NC	NC; % BD 0
C-12W	Depth 147.5' - 167.2'		1	C 6 Cy	S Sk 15 Cy	Sk 22 Cy; % BD 10.5

Table 2
Abbreviations used in tables

Abbreviation	Meaning
BD	Breakdown
C	Cracking
Cv	Cleaving
Cy	Cycle
F	Freeze-thaw sample
Fr	Friable
NC	No change
ND	Not determined
P	Peeling
S	Slight (Slightly)
Sat	Saturated
Sc	Scouring
Sk	Slaking
Sp	Slumping
Sv	Severe
Sw	Swelling
v	Very
W	Wet-dry sample
%	Percent



1. Original condition.

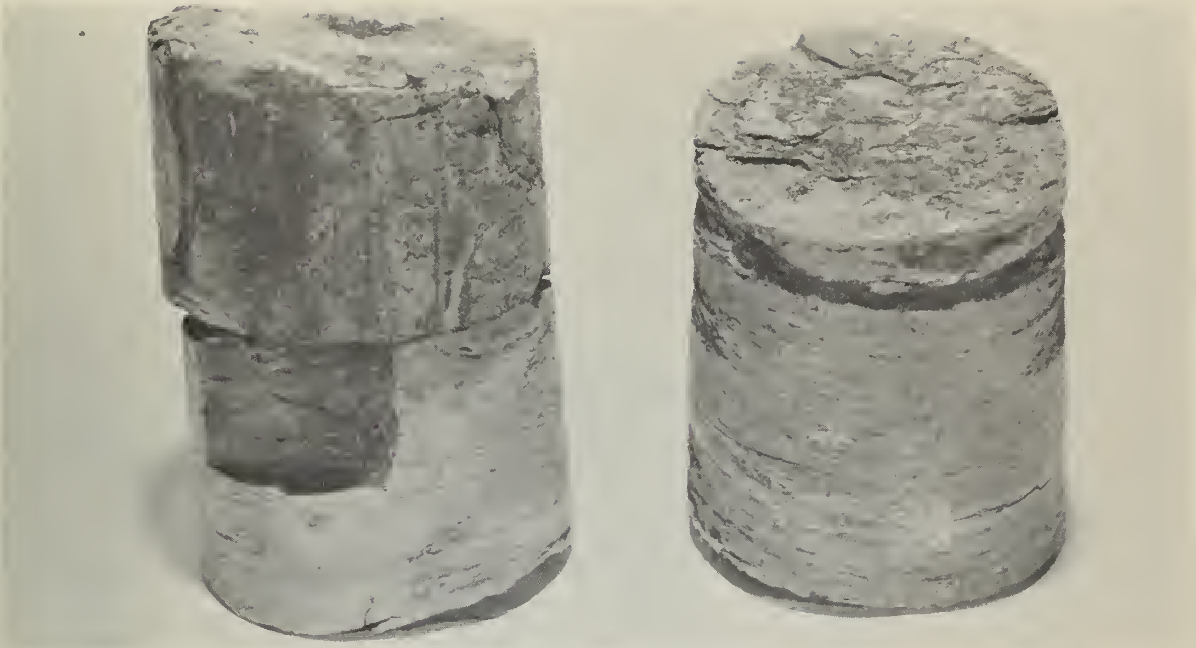


2. Condition after 30 weathering cycles.

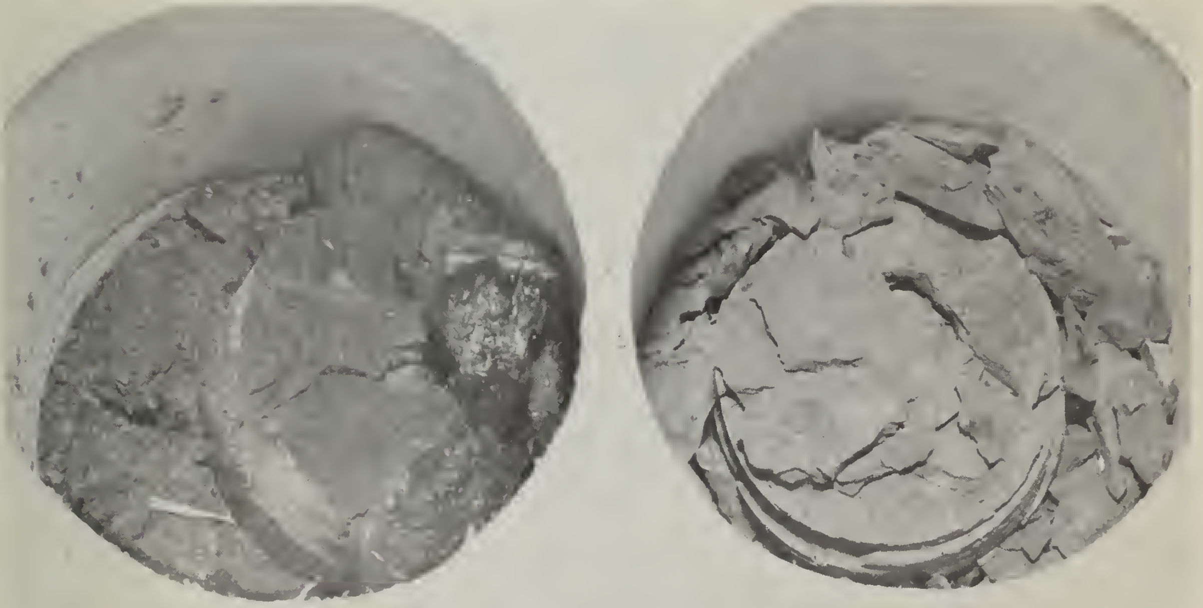
Figure 1--Results of laboratory weathering for sandstone sample from Craig, Colo.; DH 102, depth 34.2' to 47.7'. Sample on left was subjected to freezing-thawing; sample on right was subjected to wetting-drying.

[illegible]

[illegible]



1. Original condition.



2. Condition after 30 weathering cycles.

Figure 2--Results of laboratory weathering for shale sample from Craig, Colo.; DH 102, depth 47.7' to 55.5'. Sample on left was subjected to freezing-thawing; Sample on right was subjected to wetting-drying.

Table 3
Dry gradation analysis

Sieve size	Cumulative percent passing by weight				
	K-1F	K-1W	K-10F	K-10W	OC-3F
4	100.0	93.8	97.3	61.6	92.8
10	99.8	21.2	96.5	20.8	82.8
50	17.3	1.8	25.0	3.3	26.7
100	6.7	.9	7.7	2.2	20.7
200	2.8	.5	3.6	2.1	17.2
	C-3F	C-3W	C-5F	C-5W	OC-8F
4	100.0	45.0	100.0	50.9	100.0
10	100.0	15.4	92.5	12.5	99.9
50	29.1	4.8	24.6	2.5	48.6
100	14.8	2.9	9.5	1.3	28.4
200	8.7	2.0	4.2	.8	8.7
	C-7F	C-7W	H-5F	H-7F	
4	92.8	62.7	98.4	99.5	
10	85.1	23.2	97.0	98.5	
50	33.0	4.4	52.4	45.9	
100	19.8	2.5	29.4	28.1	
200	13.1	1.9	11.1	10.9	

Note: Samples dried for 48 hours at 100° F. before gradation analysis.

Of the 41 samples tested, approximately 40 percent exhibited sufficient breakdown to attain the texture required for topsoil, that is, 30 percent by weight of the soil passing the No. 10 screen. In the field, however, these materials, primarily shales, will probably weather at different rates, and this will require various methods of handling, storing, and processing before they are suitable for use as topsoil in revegetation.

Approximately 25 percent of the samples tested showed some swelling characteristics and other deleterious properties that might preclude their use in revegetation. Such materials might find application, however, in constructing impervious blankets to isolate problem soils during replacement of the overburden materials.

About 10 percent of the samples tested showed no effects of weathering. Most of these materials were well cemented sandstones. In the field such materials might find application in the construction of french drains and outslope foundations.

APPENDIX D

SITE HYDROLOGY AND VEGETATION

APPENDIX D

SITE HYDROLOGY AND VEGETATION

This appendix contains water quality summary data from sampling stations as shown in Tables 1 and 2. Well logs from observation wells drilled by the Geological Survey are shown in Tables 3, 4, 5, and 6. Table 7 is a summary of water level measurements of all observation wells monitored by the Geological Survey.

The period of record is short since most stations were not in operation prior to the study. Collection of data will continue, however, as the site hydrology and water quality study is a continuing one.

The complete water quality data are available from records maintained by the United States Department of the Interior, Geological Survey, Denver Federal Center, Denver, Colo.

Also included as a part of this appendix are supporting and informative data developed during the vegetation, soil-moisture-retention characteristics, and soil erodibility studies conducted by the Geological Survey.

Soil Sample Procedure and Data Presentation

Soil profiles were sampled at locations indicated on the vegetation map shown on Figure 1. Samples were obtained for each 10-centimeter-depth increment, examined in the field to define tentative horizon depths, and then sealed for transportation to the laboratory. A moisture-stress sensor (filter paper) was included in each sample.

Vegetation at each sampling site was identified, measured, and photographed to define plant community associations. Photographs of the sites and the associated average soil-moisture characteristics are shown on Figure 2.

The soils hydrologic data for each of the seven vegetative types are presented in Table 8. Definitions and methods for items reported are as follows.

H = soil horizon.--Defined hydrologically and determined during field examination but adjusted where bulk density, electrical conductivity, pH, or root data indicated a change should be made.

Table 1
Summary of water quality analysis
U.S. Geological Survey data

		Sample sites									
		A-1 Good Spring Creek at Axial, Colo.		A-2 Taylor Creek near Axial, Colo.	A-3 Wilson Creek near Axial, Colo.		A-4 Wilson Creek near East Fork		Taylor Creek Control near Axial, Colo.		A-7 Good Spring Creek at Elkhorn Creek Axial, Colo.
									A-6	A-6a	
	Unit	June 6, 1974	August 27, 1974	June 7, 1974	June 12, 1974	August 26, 1974	June 12, 1974	August 27, 1974	June 12, 1974	August 27, 1974	June 12, 1974
AKL total (AS $CaCO_3$)	MG/L	382		270	309		291		333		349
Arsenic, dissolved	UG/L	5	4	4	1	1		1		3	
Bicarbonate	MG/L	446	488	340	377	442	355	400	406	528	425
Cadium, dissolved	UG/L	1	1	1	1						
Calcium, dissolved	MG/L	110	100	83	85	85	78	84	110	98	97
Carbon dioxide	MG/L	9.4		6.8	9.6		5.7		26		6.8
Chloride, dissolved	MG/L	11	18	20	100	150	110	99	17	38	9.3
Chromium, dissolved	UG/L										
Conductivity		1,270	1,400	938	1,250	1,490	1,170	1,000	1,040	1,250	1,120
Copper, dissolved	UG/L	13	2	9	23	4		22	6	4	
Fluoride, dissolved	MG/L	.4	.5	.2	.4	.5	.4	.3	.3	.3	.5
Hardness noncarbonate	MG/L	290	380	190	130	280	81	71	210	200	240
Hardness, total	MG/L	670	790	470	440	620	370	400	540	660	590
Iron, dissolved	UG/L	50	40	70	210	50	50	20	50	50	50
Lead	UG/L	11	1	8	12	2		1	4	2	
Magnesium, dissolved	MG/L	97	130	64	56	100	43	46	64	100	84
Manganese, dissolved	UG/L	170	20		40	10	110	40	40		130
Mercury, dissolved	UG/L	.2	.5			1.5					
Molybdenum, dissolved	UG/L	2	2	2	7	1		1	2		
Nickel, dissolved	UG/L	3	4	3	4	14		5	1	1	
NO2 + NO3 as N, dissolved	MG/L	1.0	.10	.86	.51	.22	.41	.16	.38	6.7	.98
Oxygen, dissolved	MG/L	8.3		8.3	7.4		9.6		6.8		
pH		7.9	8.2	7.9	7.8	8.2	8.0	8.0	7.4	8.4	8.0
Phosphate Ortho, dissolved as P	MG/L	.03	.02	.10	.02		.01	.03	.08	.01	.03
Phosphate, dissolved Ortho	MG/L	.09	.06	.31	.06		.03	.09	.25	.03	.09
Potassium, dissolved	MG/L	9.6	13	4.9	6.6	9.3	6.0	6.2	3.3	5.3	8.9
Residue, dissolved calc. sum	MG/L	845	1,030	585	757	1,060	664	108	651	857	717
Residue, dissolved ton/aft		1.15	1.40	.80	1.03	1.44	.90	.96	.89	1.17	.98
Sar		.6	.9	.6	2.0	2.6	2.3	2.4	.4	1.3	.5
Selenium, dissolved	UG/L	2	2	2	2	.4		2	1	10	
Silica, dissolved	MG/L	14	12	11	11	8.5	10	14	14	18	14
Sodium, dissolved	MG/L	38	56	30	99	150	100	110	20	75	29
Sodium (percent)		11	13	12	32	34	36	37	7	20	10
Sulfate, dissolved	MG/L	330	460	200	210	350	140	150	220	220	260
Vanadium, dissolved	UG/L	1.0	.1	.2	1.3	.8				.3	
Water temperature (° C.)		11.5	13.5	15.5	12.0	14.5	14.5	10.0	16.0	17.0	18.5
Zinc, dissolved	UG/L	20	20	10	30	20		20	10	10	

Table 2
Summary of water quality data

	Sample site																			
	A-1				A-2		A-3				A-4				A-6		A-6a		A-7	
	June 6, 1974		August 27, 1974		June 7, 1974		June 12, 1974		June 26, 1974		June 12, 1974		August 27, 1974		June 12, 1974		August 27, 1974		June 12, 1974	
Units	MG/L	MEQ/L	MG/L	MEQ/L	MG/L	MEQ/L	MG/L	MEQ/L	MG/L	MEQ/L	MG/L	MEQ/L	MG/L	MEQ/L	MG/L	MEQ/L	MG/L	MEQ/L	MG/L	MEQ/L
Cation																				
Calcium	110	5.489	100	4.990	83	4.142	85	4.242	85	4.242	78	3.893	84	4.192	110	5.489	98	4.891	97	4.841
Magnesium	97	7.980	130	10.697	64	5.265	56	4.607	100	8.226	43	3.538	46	3.784	64	5.265	100	8.226	84	6.910
Potassium	9.6	.246	13	.333	4.9	.126	6.6	.169	9.3	.238	6.0	.154	6.2	.159	3.3	.085	5.3	.136	8.9	.228
Sodium	38	1.653	56	2.463	30	1.309	99	4.307	150	6.525	100	4.350	110	4.785	20	.870	75	3.263	29	1.262
Total		15.367		18.452		10.837		13.323		19.230		11.933		2.919		11.708		16.514		13.239
Anions																				
Bicarbonate	466	7.638	488	7.999	340	5.573	377	6.180	422	6.917	355	5.819	400	6.556	406	6.655	528	8.654	425	6.966
Chloride	11	.311	18	.508	20	.565	100	2.821	150	4.282	110	3.104	99	2.793	17	.480	38	1.072	9.3	.263
Fluoride	.4	.022	.5	.027	.2	.011	.4	.022	.5	.027	.4	.022	.3	.016	.3	.016	.3	.016	.5	.027
Sulfate	330	6.871	460	9.578	200	4.164	210	4.373	350	7.287	140	2.915	150	3.123	220	4.581	220	4.581	260	5.414
$NO_2 + NO_3$ as N D	1	.072	.1	.008	.86	.062	.51	.087	.22	.016	.41	.030	.16	.012	.38	.028	6.7	.479	.98	.070
Carbonate																	12	.400		
Total		14.911		18.117		10.373		13.430		18.477		11.887		12.499		11.757		15.200		12.738
Percent difference		1.50		.92		2.19		-.40		2.00		.19		1.65		-.21		4.14		1.93

Table 3
U.S. Geological Survey Well No. 5
NW¼NW¼ sec. 9, T. 3 N., R. 93 W.

Air-drilled depth (feet)	
0- 5	Soil.
5-15	Soil, clayey, with limonitic sandstone pebbles.
	Bit booting up.
15-20	Soil, sandy, with pebbles, as above.
20-25	Shale, gray to brown, soft, with some sandstone.
25-35	Sandstone, limonitic, fine grained; some shale.
35-45	Sandstone, limonitic, very fine grained, decomposed, friable.
45-50	Sandstone, limonitic, fine grained, to shale, gray to black.
50-55	Shale, decomposed, plastic.
55-60	Sandstone, fine grained, decomposed, coaly, with coal streak at bottom.
	Estimated yield ½ gpm at 60 feet.
60-65	Coal.
65-75	Shale, gray to black, carbonaceous, silty.
75-85	Siltstone, limonitic, with chert inclusions; some shale and coal at bottom.
85-91	Coal.
91-96	Siltstone, hard, with trace of coal.
	Estimated yield over ½ gpm.

Note: Water level November 12, 1974, 27.80 feet below land surface.

Table 4
U.S. Geological Survey Well No. 6
SE¼SW¼ sec. 3, T. 3 N., R. 93 W.

Air-drilled depth (feet)	
0- 5	Loam, brown.
5-10	Sandstone and silt, brown.
10-18	Sandstone, tan, very fine grained, with some clay.
18-23	Sandstone, brown, very fine grained, firm.
23-30	Sandstone, tan to gray, silty and shaly, carbonaceous.
30-41	Sandstone, gray, very fine grained, silty, shaly, carbonaceous.
41-54	Shale, coaly.
	Moisture at 45 feet; dry at 52 feet.
54-65	Silt, dark gray, and shale, coaly.
65-73	Sandstone, gray, very fine grained.
73-80	Siltstone, dark gray, very coaly and shaly.
80-85	Shale, gray, silty.
85-98	Sandstone, gray, very fine grained, shaly.
	Estimated yield less than ½ gpm.

Note: Water level November 12, 1974, 23.74 feet below land surface.

Table 5
U.S. Geological Survey Well No. 7
SE¼SW¼ sec. 3, T. 3 N., R. 93 W.

Water-drilled hole depth (feet)	
0- 7	Soil, sandy.
7-15	Sandstone, tan, fine grained, clayey, silty.
	Bit booted up at 14 feet.
15-20	Sandstone, buff, fine grained, silty, calcareous.
20-25	Shale, gray, decomposed, may be bentonitic.
25-35	Siltstone, gray, shaly, with some coal.
35-40	Shale, silty, and coal.
40-60	Siltstone, coaly, shale, silty, coal, and trace of sandstone.
	No estimated yield.

Note: Water level November 12, 1974, 12.72 feet below land surface.

Table 6
U.S. Geological Survey Well No. 8
NW¼NW¼ sec. 10, T. 3 N., R. 93 W.

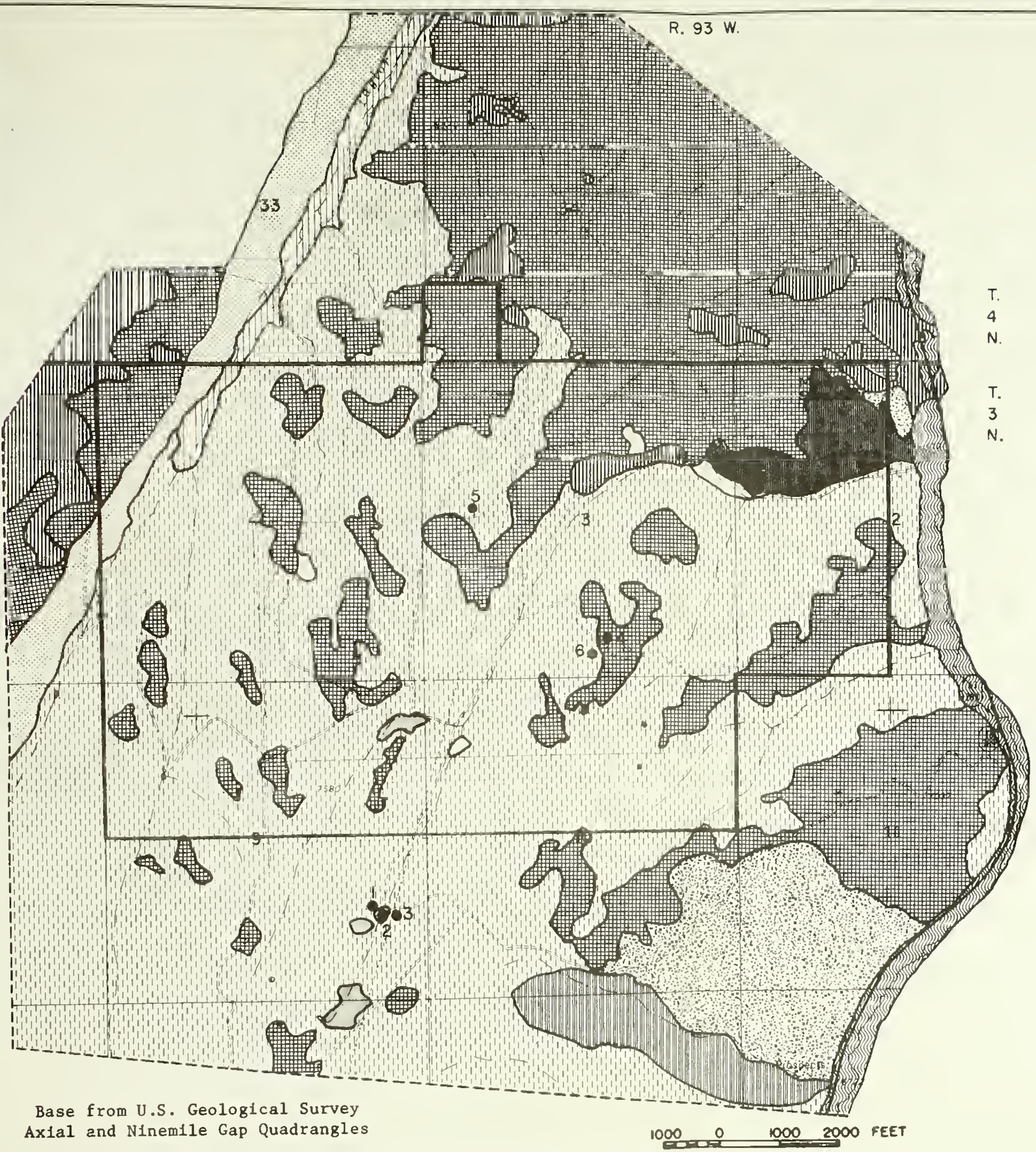
Air-drilled depth (feet)	
0- 5	Soil, dark brown, sandy, loamy.
5-15	Shale, dark brown to black.
	Bit booting up.
15-19	Sandstone, orange to black, limonitic.
19-24	Siltstone, light gray to brown, decomposed.
24-35	Shale, light gray to dark gray, with siltstone stringers.
35-39	Shale, black, organic, silty.
	Water at 39 feet.
39-45	Shale, black, flaky, with sandstone stringers.
45-50	Shale, black, and coal.
50-55	Shale, brown to black.
55-60	Shale, light gray, with trace of coal and siltstone.
60-65	Coal and shale.
	More water at 60 feet.
65-75	Shale, brown to black, with chert and coal inclusions.
75-80	Shale, gray, with some coal and friable sandstone; some pebbles less than 10 millimeters.
	Estimated yield 3 gpm.

Note: Water level November 12, 1974, 23.55 feet below land surface.

Table 7
Well logs and water-level measurements
Fall 1974

	Well number		Section	Township	Range	Depth-to-water (feet)	Altitude of water (feet)	Well depth (feet)	Remarks
U.S. Geological Survey	1	SW¼NE¼	2	3 N.	93 W.	4	6,587	25	
U.S. Geological Survey	2	NE¼SE¼	32	4 N.	93 W.	13	6,662	20	
U.S. Geological Survey	3	SW¼SE¼	33	4 N.	93 W.	Dry		25	Altitude of bottom of well, 6,785 feet.
U.S. Geological Survey	4	SE¼NW¼	10	3 N.	93 W.	17	7,568	25	300 feet from Grace 35.
U.S. Geological Survey	5	SW¼NW¼	9	3 N.	93 W.	28	7,277	96	First water at 60 feet.
U.S. Geological Survey	6	NE¼SE¼	9	3 N.	93 W.	24	7,541	98	First water at 45 feet.
U.S. Geological Survey	7	SE¼SW¼	3	3 N.	93 W.	13	7,155	60	
U.S. Geological Survey	8	NW¼NW¼	10	3 N.	93 W.	24	7,266	80	First water at 39 feet.
Grace	26	NW¼SW¼	4	3 N.	93 W.	128	6,972		
*Grace	27	NE¼NW¼	4	3 N.	93 W.	295	6,775		Water flowing down from 80 feet.
*Grace	33	SE¼NE¼	9	3 N.	93 W.	Dry at 500	(7,055 feet altitude)		Perched water seeping into hole.
*Grace	35	SE¼NW¼	10	3 N.	93 W.	Dry at 280	(7,290 feet altitude)		Perched water seeping into hole. Near U.S. Geological Survey 4.
Grace	37	SW¼NE¼	10	3 N.	93 W.	18	7,422		
Grace	45	SE¼SE¼	3	3 N.	93 W.	165	7,250		
*Grace	46	SW¼SW¼	2	3 N.	93 W.	151	7,104		
Bureau of Reclamation	101	SW¼SE¼	4	3 N.	93 W.	140	7,325	200	
Bureau of Reclamation	102	SW¼SE¼	3	3 N.	93 W.	126	7,214	199	

*Note: Not regularly measured and not on index map.



Base from U.S. Geological Survey
Axial and Ninemile Gap Quadrangles

Explanation

▥ **Serviceberry-Gambel's oak** type covers more than half the upper portion of the area. Understory species include Kentucky bluegrass, western wheatgrass, and Idaho fescue.

▦ **Big sagebrush**--covers the lower one-third of the area and is present in scattered stands in the upper two-thirds. Associated species include western wheatgrass and Kentucky bluegrass.

░ **Serviceberry-Big sagebrush**. Associated species include western wheatgrass and Kentucky bluegrass.

■ **Utah juniper-Big sagebrush**. Associated species include bluebunch wheatgrass, serviceberry, and Douglas rabbitbrush.

▥ **Serviceberry**. Where present in pure stands associated species include Idaho fescue, big sagebrush, and western wheatgrass.

░ **Big sagebrush-Serviceberry-Bluebunch wheatgrass**. Present on rocky southern exposures.

▥ **Big sagebrush-Kentucky bluegrass**. This type occurs on floodplains often associated with willows.

▧ **Hay meadows**.

▥ **Gambel's oak-Serviceberry**. Gambel's oak replaces serviceberry as the dominant on lower portions of north-facing slopes.

▩ **Quaking aspen**. Type occurs in isolated stands on floodplains or near springs at higher altitudes in the area. Kentucky bluegrass is the main understory species.

□ **Gambel's oak**. Occasionally present as pure stands.

● 2 Sampling site locations

━ Study site boundary

‐‐‐ Boundary of mapped area

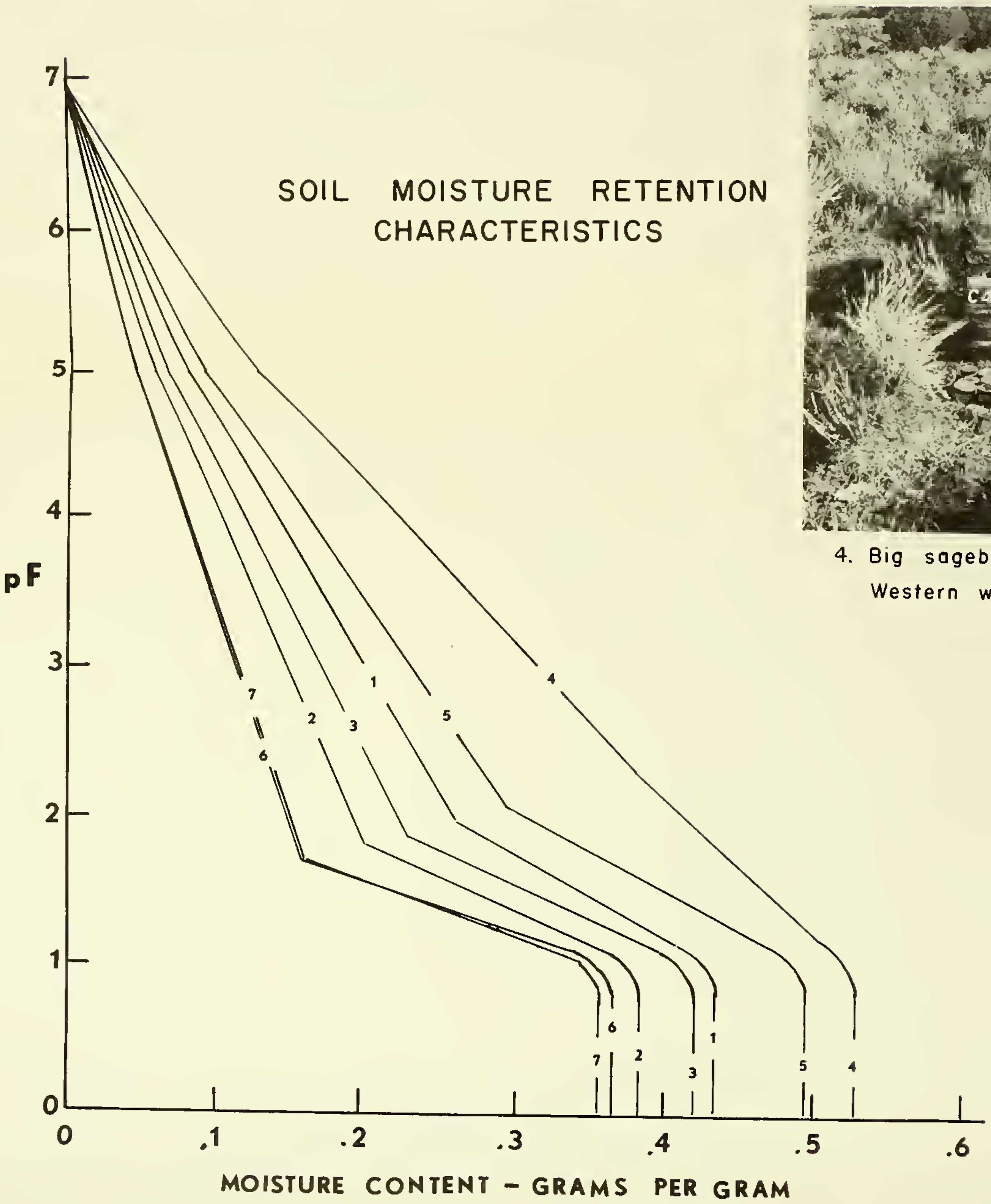
VEGETATION MAP OF THE TAYLOR CREEK EMRIA STUDY SITE, COLORADO - 1974

Figure 1

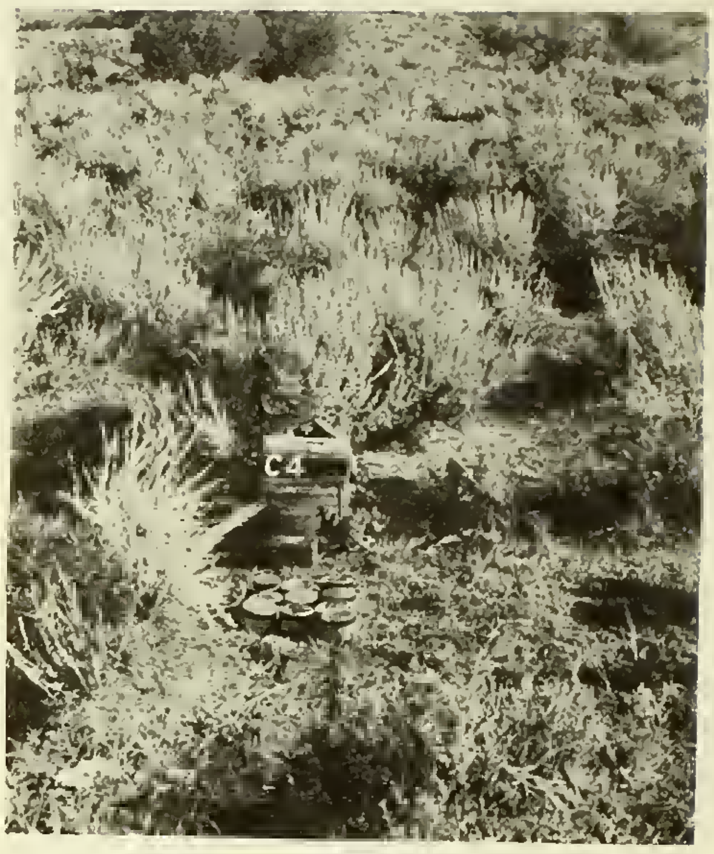
1. Big sagebrush
   Western wheatgrass

2. Quaking aspen
   Kentucky bluegrass

3. Gambels oak



SOIL MOISTURE RETENTION CHARACTERISTICS



4. Big sagebrush
   Western wheatgrass

Locations of sampling sites, identified on photographs and curves, are shown on the vegetation map, plate

5. Serviceberry - Idaho fescue
   Big sagebrush

6. Gambels oak
   Serviceberry

7. Utah juniper, Big sagebrush
   Bluebunch wheatgrass

Table 8, Sheet 1 of 7
Soil hydrologic properties

COLO SITE 1 DATE: 9/13/74 SAMPLE NO. 1 VEGETATION TYPE: Big sagebrush-Western wheatgrass

H DPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.0759	0.95	0.0	1.792	.676	.481	1.275	1.49	1.635	5.02	.388	0.093	.040	0.571	5.96	17.75	232.	.802	0.423	0.249
20	0.0954	1.07	1.01	1.631	.615	.408	1.081	1.53	1.439	4.66	.376	0.032	.053	0.526	6.18	3.55	190.	.778	0.439	0.278
30	0.1003	1.40	1.14	1.330	.502	.402	1.065	1.60	1.322	4.35	.331	0.071	.047	0.467	6.22	3.20	190.	.788	0.439	0.288
40	0.1092	1.38	1.28	1.068	.403	.410	1.087	1.60	1.336	4.19	.332	0.078	.060	0.485	6.20	1.42	296.	.682	0.405	0.188
50	0.1179	1.22	1.33	0.987	.372	.389	1.030	1.60	1.300	4.10	.344	0.045	.067	0.481	6.20	1.06	306.	.770	0.402	0.175
60	0.1222	1.30	1.30	1.039	.392	.436	1.154	1.59	1.393	3.92	.328	0.107	.050	0.490	6.24	1.42	236.	.798	0.421	0.244
1 Ave.	0.1035	1.22		1.308		.421		1.57		4.38	.350		.054	0.503	6.15			.770	0.421	0.237
70	0.1219	1.41	1.31	1.025	.387	.405	1.072	1.61	1.312	3.99	.338	0.067	.067	0.510	6.28	1.06	254.	.741	0.416	0.218
80	0.1245	1.44	1.38	0.919	.347	.424	1.124	1.57	1.404	3.99	.345	0.079	.073	0.523	6.30	.36	192.	.784	0.438	0.291
90	0.1300	1.85	1.57	0.692	.261	.411	1.090	1.59	1.352	4.08	.375	0.037	.073	0.553	6.30	.36	155.	.731	0.457	0.355
100	0.1357	1.42	1.57	0.690	.260	.395	1.046	1.68	1.200	3.99	.378	0.017	.107	0.591	6.37	.71	217.	.745	0.428	0.262
110	0.1450	1.40	1.56	0.703	.265	.426	1.128	1.60	1.361	3.95	.395	0.031	.093	0.607	6.35	.71	163.	.548	0.452	0.350
120	0.1415	1.48	1.43	0.851	.321	.415	1.099	1.63	1.300	3.93	.382	0.033	.087	0.605	6.50	.36	282.	.533	0.408	0.202
2 Ave.	0.1333	1.50		0.813		.413		1.61		3.99	.369		.083	0.565	6.35			.714	0.433	0.280
130	0.1359	1.88	1.59	0.671	.253	.415	1.099	1.60	1.343	3.80	.346	0.068	.080	0.581	6.50	.36	230.	.558	0.423	0.243
140	0.1358	1.80	1.72	0.543	.205	.394	1.043	1.67	1.212	3.82	.349	0.044	.073	0.595	6.56	.71	193.	.822	0.438	0.292
150	0.1333	1.81	1.83	0.450	.170	.420	1.114	1.65	1.281	3.81	.342	0.078	.067	0.572	6.58	.71	147.	.795	0.461	0.396
160	0.1472	1.80	1.80	0.471	.178	.418	1.107	1.64	1.291	3.88	.388	0.029	.087	0.725	6.57	.36	256.	.770	0.415	0.225
170	0.1530	1.79	1.80	0.474	.179	.430	1.140	1.65	1.297	3.84	.397	0.034	.087	0.658	6.53	.00	156.	.740	0.455	0.379
180	0.1604	1.67	1.75	0.513	.194	.445	1.178	1.64	1.334	3.87	.422	0.023	.087	0.740	6.70	.36	196.	.748	0.436	0.307
190	0.1577	1.55	1.67	0.587	.222	.425	1.126	1.59	1.375	3.83	.408	0.017	.107	0.753	6.70	.36	208.	.740	0.431	0.272
200	0.1546	1.68	1.63	0.624	.235	.419	1.111	1.59	1.366	3.84	.401	0.018	.100	0.733	6.70	.36	183.	.732	0.442	0.306
210	0.1555	1.69	1.64	0.615	.232	.440	1.167	1.63	1.341	3.80	.400	0.040	.107	0.727	6.73	.00	200.	.647	0.435	0.297
220	0.1563	1.53	1.63	0.622	.235	.473	1.253	1.61	1.424	3.88	.412	0.060	.100	0.760	6.69	.00	88.	.675	0.514	0.701
230	0.1507	1.52	1.58	0.675	.255	.442	1.173	1.64	1.331	3.75	.377	0.065	.093	0.762	7.05	.00	136.	.584	0.469	0.442
240	0.1591	1.56	1.54	0.724	.273	.455	1.206	1.62	1.380	3.69	.388	0.067	.080	0.755	7.40	.00	169.	.582	0.449	0.358
250	0.1591	1.46	1.51	0.753	.284	.463	1.279	1.55	1.535	3.86	.416	0.067	.093	0.696	7.45	.36	142.	.575	0.465	0.424
260	0.1565	1.48	1.50	0.767	.290	.466	1.234	1.58	1.458	3.77	.394	0.071	.093	0.710	7.49	.00	153.	.727	0.458	0.392
270	0.1604	1.19	1.38	0.925	.349	.492	1.304	1.57	1.518	3.58	.376	0.116	.093	0.633	7.48	0.0	170.	.664	0.448	0.363
280	0.1717	1.77	1.48	0.790	.298	.469	1.243	1.64	1.374	3.68	.418	0.052	.087	0.636	7.52	0.0	132.	.749	0.472	0.473
3 Ave.	0.1530	1.64		0.638		.443		1.62		3.79	.390		.090	0.690	6.93			.707	0.451	0.367
Profile Ave.	0.1392	1.52		0.819		****		1.61		3.96	.377		.081	******	6.64			.722	*****	0.320

Table 8, Sheet 2 of 7
Soil hydrologic properties

COLO SITE 2 DATE: 9/13/74 SAMPLE NO. 1 VEGETATION TYPE: Quaking aspen-Kentucky bluegrass

H	DPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
	10	0.0626	0.91	0.0	1.899	.716	.576	1.526	1.46	1.860	5.38	.453	0.123	.053	0.521	6.52	7.23	94.	.822	0.507	0.676
	20	0.1097	1.22	1.07	1.480	.558	.513	1.359	1.43	1.803	4.52	.397	0.116	.040	0.424	6.51	2.26	82.	.710	0.523	0.705
	30	0.1089	1.07	1.07	1.479	.558	.425	1.127	1.57	1.406	4.21	.334	0.091	.040	0.356	6.50	1.81	66.	.737	0.550	0.846
	40	0.1063	1.30	1.20	1.213	.458	.420	1.114	1.55	1.428	4.19	.323	0.097	.040	0.330	6.48	1.58	76.	.677	0.532	0.721
	50	0.1177	1.13	1.17	1.274	.481	.452	1.199	1.53	1.515	3.80	.301	0.152	.040	0.347	6.50	1.36	3.	.672	2.096	18.951
	60	0.1275	1.29	1.24	1.137	.429	.431	1.143	1.60	1.371	3.62	.304	0.128	.040	0.345	6.40	1.13	71.	.737	0.540	0.811
	70	0.1249	0.98	1.13	1.336	.504	.435	1.153	1.57	1.422	3.60	.295	0.140	.033	0.321	6.34	.90	26.	.679	0.707	2.178
1	Ave.	0.1082	1.13		1.402		.465		1.53		4.19	.344		.041	0.378	6.49			.719	0.779	3.555
	80	0.1206	1.32	1.20	1.213	.458	.424	1.123	1.64	1.301	3.74	.300	0.124	.040	0.336	6.35	.68	14.	.753	0.873	4.162
	90	0.1190	1.68	1.33	0.996	.376	.436	1.156	1.59	1.394	3.80	.303	0.133	.040	0.321	6.28	.45	28.	.704	0.691	2.056
	100	0.1183	1.47	1.49	0.779	.294	.388	1.029	1.58	1.328	3.70	.291	0.098	.033	0.301	6.25	.68	42.	.691	0.616	1.255
	110	0.1171	1.36	1.50	0.764	.288	.360	0.954	1.60	1.252	3.66	.283	0.077	.053	0.316	6.20	.45	120.	.855	0.481	0.421
	120	0.1127	1.52	1.45	0.829	.313	.406	1.076	1.64	1.272	3.57	.263	0.143	.040	0.330	6.20	.90	71.	.764	0.540	0.796
	130	0.1021	1.58	1.49	0.783	.295	.374	0.991	1.66	1.194	3.57	.239	0.135	.040	0.323	6.20	.90	52.	.900	0.583	1.038
2	Ave.	0.1150	1.49		0.894		.398		1.62		3.67	.280		.041	0.321	6.25			.778	0.631	1.622
	140	0.0815	1.59	1.56	0.696	.262	.335	0.887	1.71	1.069	3.55	.189	0.146	.027	0.225	6.23	.68	15.	.925	0.850	3.414
	150	0.0773	1.61	1.59	0.666	.251	.298	0.791	1.77	0.944	3.41	.171	0.128	.013	0.208	6.21	.45	27.	.917	0.699	1.798
	160	0.0884	1.58	1.59	0.665	.251	.274	0.726	1.83	0.845	3.39	.193	0.080	.027	0.239	6.20	.23	71.	.869	0.540	0.661
	170	0.0940	1.47	1.55	0.707	.267	.343	0.909	1.72	1.069	3.48	.212	0.131	.033	0.259	6.15	.00	71.	.889	0.540	0.739
	180	0.1104	1.68	1.58	0.679	.256	.301	0.796	1.71	1.015	3.37	.240	0.060	.027	0.321	6.13	.23	120.	.777	0.481	0.393
	190	0.0953	1.83	1.66	0.596	.225	.212	0.561	1.88	0.708	3.47	.214	-.003	.007	0.208	6.12	.23	68.	.579	0.546	0.576
	200	0.1087	1.72	1.74	0.519	.196	.233	0.618	1.81	0.805	3.19	.222	0.011	.007	0.227	6.12	.23	38.	.467	0.633	1.075
3	Ave.	0.0937	1.64		0.647		.285		1.78		3.41	.206		.020	0.241	6.17			.775	0.613	1.237
	Pro- file Ave.	0.1052	1.42		0.985		.382		1.64		3.76	.276		.034	0.313	6.30			.756	0.676	2.164

Table 8, Sheet 3 of 7
Soil hydrologic properties

COLO SITE 3 DATE: 9/13/74 SAMPLE NO. 1 VEGETATION TYPE: Gambels Oak

H DEPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.1219	0.62	0.0	3.280	****	.546	1.446	1.46	1.806	4.29	.388	0.157	.047	0.524	6.00	3.34	1408.	.777	0.318	0.043
20	0.1214	0.67	0.64	3.122	****	.510	1.351	1.47	1.722	4.40	.410	0.100	.040	0.481	6.12	3.34	1417.	.567	0.317	0.041
30	0.1179	0.98	0.75	2.516	.949	.472	1.251	1.50	1.600	4.23	.364	0.108	.033	0.479	6.10	2.67	76.	.777	0.532	0.754
40	0.1194	0.99	0.88	2.023	.763	.469	1.242	1.49	1.612	4.16	.358	0.111	.047	0.488	6.00	1.67	83.	.565	0.521	0.683
50	0.1235	1.11	1.02	1.590	.600	.440	1.166	1.46	1.614	4.04	.350	0.090	.047	0.505	6.02	2.67	185.	.683	0.441	0.298
1 Ave.	0.1208	0.87		2.506		.487		1.48		4.22	.374		.043	0.495	6.05			.714	0.426	0.362
60	0.1139	1.33	1.14	1.324	.500	.388	1.029	1.56	1.358	4.04	.323	0.066	.053	0.510	5.92	1.00	141.	.769	0.465	0.359
70	0.1150	1.43	1.29	1.057	.399	.391	1.037	1.64	1.248	3.94	.312	0.080	.067	0.538	5.80	.67	172.	.883	0.447	0.320
80	0.1187	1.49	1.42	0.872	.329	.379	1.005	1.63	1.242	3.84	.308	0.071	.060	0.569	5.76	.67	350.	.765	0.393	0.153
90	0.1404	1.81	1.58	0.679	.256	.418	1.107	1.61	1.333	3.69	.344	0.074	.073	0.595	5.60	1.67	366.	.788	0.390	0.156
100	0.1205	1.84	1.71	0.547	.206	.396	1.049	1.64	1.256	3.91	.322	0.074	.067	0.581	5.65	1.00	428.	.748	0.380	0.130
2 Ave.	0.1217	1.58		0.896		.394		1.62		3.88	.322		.064	0.559	5.75			.790	0.415	0.225
110	0.1188	1.47	1.71	0.551	.206	.389	1.031	1.61	1.286	3.73	.295	0.094	.067	0.556	5.60	1.00	274.	.776	0.410	0.196
120	0.1203	2.01	1.78	0.493	.186	.411	1.089	1.62	1.308	3.81	.309	0.102	.067	0.617	5.51	.67	285.	.826	0.407	0.197
130	0.1183	1.86	1.78	0.485	.183	.407	1.080	1.64	1.274	3.78	.299	0.108	.080	0.611	5.53	.67	176.	.828	0.445	0.321
140	0.1206	1.66	1.85	0.436	.165	.393	1.042	1.63	1.265	3.82	.310	0.083	.067	0.610	5.62	1.34	223.	.750	0.426	0.246
150	0.1177	1.56	1.73	0.535	.202	.383	1.015	1.63	1.248	3.69	.288	0.095	.057	0.638	5.66	.67	93.	.827	0.508	0.579
160	0.1217	1.21	1.51	0.759	.286	.376	0.997	1.66	1.197	3.60	.287	0.089	.080	0.580	5.67	.33	82.	.861	0.523	0.660
170	0.1303	1.26	1.37	0.928	.350	.393	1.042	1.64	1.251	3.59	.306	0.087	.073	0.674	5.68	1.00	141.	.820	0.465	0.392
180	0.1239	1.29	1.25	1.115	.421	.393	1.040	1.63	1.264	3.50	.282	0.110	.060	0.698	5.72	1.00	24.	.862	0.725	2.285
190	0.1347	1.31	1.29	1.057	.399	.411	1.089	1.61	1.322	3.53	.310	0.101	.080	0.714	5.73	1.34	64.	.857	0.554	0.875
200	0.1363	1.39	1.33	0.988	.373	.416	1.102	1.61	1.331	3.39	.299	0.117	.067	0.679	5.88	1.34	44.	.919	0.608	1.283
210	0.1360	1.22	1.31	1.026	.387	.409	1.083	1.62	1.305	3.43	.301	0.107	.080	0.679	5.98	1.00	25.	.829	0.715	2.243
220	0.1405	1.57	1.39	0.904	.341	.434	1.149	1.63	1.331	3.43	.311	0.122	.067	0.794	6.39	.67	6.	.874	1.285	9.806
240	0.1417	1.56	1.45	0.831	.314	.417	1.105	1.61	1.332	3.31	.301	0.116	.067	0.735	6.67	.67	14.	.829	0.873	4.038
250	0.1427	1.59	1.57	0.684	.258	.383	1.016	1.68	1.182	3.18	.291	0.093	.053	0.710	6.85	.67	16.	.740	0.830	3.474
3 Ave.	0.1288	1.50		0.771		.401		1.63		3.56	.299		.070	0.664	5.89			.829	0.627	1.900
Profile Ave.	0.1257	1.39		1.158		.418		1.59		3.76	.319		.063	0.607	5.89			.797	0.541	1.230

Table 8, Sheet 4 of 7
Soil hydrologic properties

COLO SITE 4 DATE: 9/13/74 SAMPLE NO. 1 VEGETATION TYPE: Big sagebrush-Western wheatgrass

H DEPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.1901	0.74	0.0	2.595	.979	.499	1.323	1.49	1.667	3.54	.439	0.061	.113	0.919	7.12	7.78	1440.	.639	0.317	0.041
20	0.1548	1.55	1.20	1.217	.459	.536	1.421	1.51	1.695	4.65	.605	-.069	.133	1.033	7.34	3.11	114.	.469	0.486	0.551
30	0.1645	1.31	1.23	1.146	.433	.548	1.451	1.50	1.734	4.46	.581	-.033	.147	0.906	7.40	1.87	119.	.621	0.482	0.532
1 Ave.	0.1698	1.23		1.653		.528		1.50		4.22	.542		.131	0.953	7.29			.576	0.428	0.375
40	0.1519	1.33	1.43	0.851	.321	.504	1.337	1.56	1.555	4.43	.523	-.018	.127	0.887	7.50	.93	93.	.658	0.508	0.672
50	0.1581	1.50	1.38	0.921	.347	.525	1.391	1.50	1.694	4.39	.533	-.008	.133	0.839	7.53	.62	122.	.730	0.479	0.505
60	0.1625	1.42	1.42	0.870	.328	.538	1.426	1.48	1.754	4.41	.553	-.015	.120	0.903	7.45	.62	80.	.758	0.525	0.772
2 Ave.	0.1575	1.42		0.881		.522		1.51		4.41	.536		.127	0.876	7.49			.715	0.504	0.649
70	0.1890	1.68	1.53	0.727	.274	.447	1.183	1.61	1.381	4.35	.623	-.176	.013	0.607	7.40	.93	13.	.284	0.898	4.559
80	0.1110	1.75	1.62	0.639	.241	.500	1.326	1.56	1.549	4.39	.373	0.127	.113	0.653	7.53	1.24	104.	.706	0.496	0.596
90	0.1105	1.62	1.68	0.576	.217	.463	1.226	1.60	1.422	3.75	.276	0.186	.067	0.571	7.92	.93	82.	.847	0.523	0.736
100	0.3537	1.65	1.67	0.585	.221	.701	1.859	1.75	1.577	4.74	****	-.763	.033	0.287	8.00	.62	37.	.806	0.538	2.323
3 Ave.	0.1911	1.67		0.632		.528		1.63		4.31	.684		.057	0.529	7.74			.561	0.638	2.054
Profile Ave.	0.1746	1.47		1.013		.526		1.55		4.31	.597		.100	0.760	7.53			.652	0.535	1.129

Table 8, Sheet 5 of 7
Soil hydrologic properties

COLO SITE 5 DATE: 9/13/74 SAMPLE NO. 1 VEGETATION TYPE: Serviceberry-Big sagebrush-Idaho fescne

H DPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.1892	0.69	0.0	2.850	****	.584	1.548	1.41	1.977	3.02	.367	0.218	.053	0.543	6.85	20.00	469.	.842	0.374	0.131
20	0.1028	1.10	0.89	1.966	.742	.482	1.277	1.50	1.618	4.47	.362	0.120	.060	0.595	6.87	2.50	169.	.722	0.449	0.344
30	0.1111	1.72	1.17	1.268	.479	.407	1.079	1.62	1.302	4.42	.380	0.027	.060	0.636	6.80	2.00	300.	.647	0.404	0.185
1 Ave.	0.1344	1.17		2.028		.491		1.51		3.97	.370		.058	0.592	6.84			.737	0.409	0.221
40	0.1280	1.73	1.52	0.748	.282	.439	1.164	1.57	1.429	4.40	.432	0.007	.080	0.833	6.90	1.75	103.	.558	0.497	0.554
50	0.1500	1.53	1.66	0.597	.225	.491	1.301	1.56	1.532	4.45	.522	-.031	.093	0.859	7.25	1.25	109.	.448	0.491	0.562
60	0.1518	1.69	1.65	0.606	.229	.494	1.310	1.58	1.507	4.46	.532	-.037	.100	0.822	7.45	.50	74.	.442	0.535	0.842
70	0.1623	1.43	1.55	0.712	.269	.533	1.414	1.55	1.622	4.44	.562	-.028	.120	0.799	7.56	1.50	30.	.508	0.677	2.145
80	0.1681	1.42	1.51	0.751	.284	.553	1.465	1.54	1.672	4.44	.581	-.028	.140	0.822	7.70	1.25	103.	.570	0.497	0.635
2 Ave.	0.1520	1.56		0.683		.502		1.56		4.44	.526		.107	0.827	7.37			.506	0.539	0.948
90	0.1591	1.65	1.50	0.766	.269	.585	1.550	1.51	1.762	4.35	.523	0.062	.140	0.839	7.70	1.00	84.	.570	0.520	0.789
100	0.1346	1.66	1.58	0.677	.255	.517	1.371	1.59	1.529	4.32	.436	0.081	.113	0.625	7.93	.50	122.	.579	0.479	0.530
110	0.1001	1.95	1.76	0.509	.192	.451	1.196	1.66	1.317	4.18	.303	0.148	.087	0.479	7.91	.50	141.	.722	0.465	0.435
120	0.0648	1.34	1.65	0.604	.228	.392	1.038	1.68	1.195	4.24	.202	0.190	.040	0.346	8.00	.25	34.	.890	0.653	1.660
3 Ave.	0.1146	1.65		0.639		.486		1.61		4.27	.366		.095	0.572	7.88			.590	0.529	0.854
Profile Ave.	0.1352	1.49		1.005		.494		1.56		4.27	.433		.091	0.683	7.41			.625	0.503	0.735

Table 8, Sheet 6 of 7
Soil hydrologic properties

COLO SITE 6 DATE: 9/13/74 SAMPLE NO. 1 VEGETATION TYPE: Gambels oak-Serviceberry

H DPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.1530	0.80	0.0	2.328	.878	.512	1.356	1.52	1.635	2.31	.243	0.269	.027	0.605	6.10	4.38	393.	.827	0.385	0.155
20	0.0808	0.85	0.82	2.222	.838	.500	1.325	1.52	1.615	4.38	.271	0.229	.040	0.431	6.40	1.46	811.	.545	0.344	0.074
30	0.0811	1.03	0.89	1.967	.742	.484	1.282	1.58	1.489	4.36	.269	0.215	.033	0.405	6.45	1.61	974.	.585	0.335	0.063
40	0.0806	1.19	1.02	1.590	.600	.480	1.271	1.56	1.513	4.32	.262	0.218	.027	0.376	6.45	1.31	794.	.846	0.345	0.075
50	0.0810	1.19	1.14	1.328	.501	.446	1.181	1.55	1.455	4.23	.250	0.195	.033	0.347	6.34	1.17	119.	.674	0.482	0.482
60	0.0782	1.29	1.22	1.167	.440	.411	1.089	1.60	1.337	4.28	.248	0.163	.027	0.329	6.30	1.02	97.	.732	0.503	0.574
1 Ave.	0.0925	1.06		1.767		.472		1.55		3.98	.257		.031	0.416	6.34			.735	0.399	0.237
70	0.0761	1.22	1.23	1.148	.433	.331	0.877	1.70	1.075	4.24	.236	0.095	.033	0.267	6.14	.73	117.	.729	0.484	0.430
80	0.0792	1.54	1.35	0.963	.363	.355	0.940	1.67	1.150	4.03	.224	0.131	.033	0.291	6.08	.73	110.	.751	0.490	0.475
90	0.0788	1.78	1.52	0.748	.282	.311	0.825	1.69	1.056	4.08	.227	0.084	.027	0.309	6.04	.88	113.	.770	0.487	0.424
100	0.0774	1.41	1.58	0.678	.256	.348	0.921	1.67	1.138	4.39	.261	0.087	.033	0.281	6.10	.73	92.	.769	0.509	0.559
110	0.0662	1.41	1.53	0.728	.275	.325	0.861	1.71	1.053	4.03	.187	0.138	.033	0.250	6.02	.58	124.	.592	0.478	0.404
2 Ave.	0.0755	1.47		0.853		.334		1.69		4.15	.227		.032	0.280	6.08			.742	0.489	0.458
120	0.0466	1.53	1.45	0.830	.313	.251	0.666	1.87	0.773	4.00	.129	0.122	.0	0.181	6.13	.29	50.	.567	0.589	0.895
130	0.0456	1.87	1.60	0.654	.247	.212	0.551	1.87	0.717	3.94	.123	0.088	.007	0.167	6.17	.44	94.	.523	0.507	0.415
140	0.0453	1.81	1.74	0.527	.199	.252	0.668	1.83	0.813	3.89	.120	0.132	.0	0.167	6.15	.44	59.	.513	0.565	0.745
150	0.0519	1.56	1.75	0.517	.195	.241	0.639	1.77	0.858	3.93	.140	0.101	.013	0.195	6.23	.29	115.	.538	0.485	0.357
3 Ave.	0.0473	1.69		0.632		.239		1.83		3.94	.128		.005	0.177	6.17			.585	0.536	0.603
Profile Average	0.0748	1.37		1.160		.364		1.67		4.03	.213		.024	0.307	6.21			.697	0.466	0.409

Table 8, sheet 7 of 7
Soil hydrologic properties

COLO SITE 7 DATE: 9/13/74 SAMPLE NO. 1 VEGETATION TYPE: Utah juniper-Big sagebrush-Bluebunch wheatgrass

DEPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.0813	1.15	0.0	1.310	.444	.372	0.986	1.74	1.090	4.23	.251	0.121	.020	0.465	6.89	2.90	25.	.535	0.715	2.246
20	0.0594	1.68	1.41	0.876	.331	.329	0.873	1.69	1.085	4.67	.236	0.094	.0	0.355	7.20	1.16	6.	.426	1.285	8.332
1Ave.	0.0704	1.41		1.093		.351		1.71		4.45	.244		.010	0.410	7.04			.481	1.000	5.289
30	0.0324	1.74	1.52	0.743	.280	.248	0.657	1.79	0.847	4.49	.116	0.132	.0	0.195	7.46	.58	15.	.309	0.850	2.830
40	0.0445	1.71	1.71	0.552	.208	.314	0.833	1.76	0.979	4.34	.146	0.168	.007	0.237	7.42	.46	16.	.570	0.830	3.140
50	0.0428	1.83	1.76	0.507	.191	.274	0.726	1.79	0.886	4.43	.147	0.127	.020	0.229	7.49	.35	13.	.566	0.898	3.534
60	0.0461	2.25	1.93	0.374	.141	.324	0.857	1.78	0.970	4.34	.151	0.173	.040	0.259	7.53	.23	36.	.798	0.643	1.439
2 Ave.	0.0415	1.88		0.544		.290		1.78		4.40	.140		.017	0.230	7.47			.561	0.805	2.736
70	0.1148	1.50	1.86	0.426	.161	.432	1.144	1.63	1.328	4.10	.334	0.098	.067	0.581	7.40	.58	1440.	.507	0.317	0.041
80	0.0885	1.86	1.87	0.419	.158	.471	1.249	1.63	1.392	4.40	.299	0.172	.093	0.459	7.70	.70	35.	.735	0.648	1.775
90	0.0811	1.90	1.75	0.511	.193	.448	1.187	1.61	1.383	4.45	.281	0.166	.087	0.402	8.05	.46	49.	.801	0.592	1.209
100	0.0719	1.98	1.92	0.383	.144	.373	0.988	1.75	1.079	4.32	.233	0.140	.053	0.368	8.06	.35	80.	.612	0.525	0.708
110	0.0591	1.68	1.86	0.428	.162	.332	0.880	1.72	1.052	4.42	.202	0.130	.040	0.355	8.20	.46	103.	.650	0.497	0.497
3 Ave.	0.0831	1.78		0.433		.411		1.67		4.34	.270		.068	0.433	7.98			.681	0.516	0.846
Pro-file Average	0.0656	1.75		0.594		.356		1.72		4.38	.218		.039	0.355	7.58			.601	0.709	2.341

1 = that portion of the soil profile that is wetted by capillary or gravity flow during recharge events. The A horizon or leached zone.

2 = that portion of the soil profile that receives moisture after recharge events by displacement of the moisture in the 1 horizon. Moisture movement is usually in the form of film flow. A zone of accumulation of clay and salts. Usually corresponds to the B horizon.

3 = that portion of the soil profile that normally receives moisture in the vapor phase. A zone of minimal moisture change. May coincide with the B-2 horizon.

4 = that portion of the soil profile with no evidence of live roots. This usually represents the top of the C horizon.

DPTH = sampling depth in centimeters.--The depth reported is the depth in centimeters to the bottom of the sample.

SM = soil moisture or moisture content of the sample in grams of water per gram of dry soil.

VOL WT = bulk density or apparent volume-weight in grams per cubic centemiter.--Computed as the dry weight of the soil sample in grams divided by the product of the mean cross-sectional area of the augered hole and the sampling depth increment.

VOL (AVE) = average bulk density or average apparent volume-weight in grams per cubic centimeter, computed as a moving average.--Each figure is the average of three consecutive figures in the preceding column. This computing technique reduces the variability introduced when the auger does not retain the same volume of soil even though the depth to which it is driven is precisely controlled.

FVR = field void ratio.--The ratio of the volume of voids to the volume of solids. Computed from the average bulk density by assuming that the density of the solids is 2.65 grams per cubic centimeter. The formula is FVR = d_S/d_B-1 where d_S = specific gravity of soil particles and d_B = volume weight or bulk density of the soil in situ (Krynine, 1947 p. 45).

VMC = voids moisture capacity.--The weight of water in grams that would fill the voids in a unit volume (1cc) of soil if the soil mass were confined so that the field bulk density is maintained. Computed as: VMC=FVR/2.65 (Krynine, 1947, p. 32).

SMC = saturation moisture capacity.--The maximum moisture that a sample will adsorb under free-swell disturbed conditions; the moisture content at ultimate hydration. Richards et al., (1954), method 2 or ASTM (1958) Designation D 426-39.

TVR = void ratio for completely saturated sample computed as 2.65 SMC (Krynine, 1947 p.32).

G/cc = total density of saturated paste.--Determined by weighting 100 cubic centimeters of saturated paste after tapping the container on a solid surface to remove the larger air bubbles.

SVR = saturated void ratio.--Void ratio of saturated paste computed from SMC and total density of saturated paste. This void ratio exceeds TVR by the volume of minute bubbles of air retained in the paste.

pF = the moisture retention force existing in the soil at the time of sampling.--Reported is the logarithm of the height of a column of water supported by an equivalent force. pF is measured using the method of McQueen and Miller (1968). This is usually designated as lower case p and upper case F but the computer does not print lower case letters.

AMC = adsorbed moisture capacity.--This represents the moisture content in grams required to satisfy all of the molecular adsorptive forces exerted by a gram of soil particles. Computed as AMC = -6.25 SM/(pF-6.25). This value is the intercept of the adsorbed segment of the mositure characteristic with the X (or zero pF) axis.

CMC = capillary moisture capacity.--Computed as SMC-AMC. Where this value is negative it means that the soil moisture characteristic probably can have no capillary segment because the pores are too small.

LS = linear shrinkage.--Ratio of the change in diameter of a cylindrical pat of saturated paste during desiccation to the original diameter of the saturated pat.

EC = electrical conductivity of saturated paste.--Richards et al. (1954), method 5 except that a two-prong stainless steel probe is used in place of the Bureau of Soils electrode cup.

PH = the negative logarithm of the hydrogen ion concentration in the saturated paste.--Richards et al. (1954), method 21a.

Roots = The roots in each sample were separated from the soils by a process of elutriation and sieving. The material retained

on a 60-mesh sieve was examined and the relative concentration of roots in each sample was estimated. The concentration of roots in the second sample (10 to 20 centimeters) was given a value of 1, and the other samples were given relative numbers. The weight of roots in the second sample was determined by drying and weighing, then this weight was multiplied by the relative numbers to provide an estimate of the weight of roots in each sample.

ET = erosion time (minutes).--Time in minutes required to erode the sample after it has been saturated, puddled, placed in a cylindrical container, allowed to air dry, removed from its container, and subjected to an erosive force that simulates a flowing stream with a velocity of 0.58 meter per second measured about 2 centimeters from the eroding surface.

TRAN = the ratio of transportable to total weight of soil.--A 60-mesh (0.25 millimeter) sieve has been arbitrarily chosen to define the boundary between suspended and bedload material. Those particles smaller than 0.25 millimeter can be suspended in a moderately turbulent stream. Particles larger than 0.25 millimeter will usually be bedload.

EK = erodibility constant.--Computed as the reciprocal of the logarithm of the erosion time. $EK = 1/\log_{10}ET$. This relationship is discontinuous at ET = 1 and because short erosion times are difficult to measure accurately, for samples where ET approached 1 minute, a value of 2 minutes was arbitrarily assigned. Also, when a sample had not disintegrated after 24 hours in the erosion test device it was removed and arbitrarily assigned a time of 24 hours. (Note: EK is similar in form to the K value defined by Wischmeier et al. (1969), for use in the universal soil-loss equation. It should not be considered as a replacement or duplication, however, because it is derived from erosion tests instead of grain size data. Parallel tests have not been conducted to define the relationships between EK and K.

IR = infiltration rate.--Computed from the dimensions of the saturated soil pat and the erosion time by assuming that when erosion is complete, sufficient water has entered the pat to completely saturate it. When an erosion pat is reinforced with roots or gravel particles in a clay matrix, its ET may be extended and the computed IR may be too small. IR, as reported, should be considered as a minimum infiltration rate in cubic centimeters per square centimeter per hour.

Discussion

An objective of this study was to define the hydrologic characteristics of soils associated with vegetation types existing on sites proposed for surface mining of coal. Many hydrologic properties of soils are not constant but can change one or two orders of magnitude under natural conditions. Greater changes can be expected during the disturbance of mining operations.

One property of a soil that will not change appreciably is its specific surface. Hydrologic characteristics that are functions of specific surface can be defined for individual soil samples or for mixtures of soils. The adsorbed film segment of the moisture retention characteristic of a soil is a direct function of the specific surface and can be defined by a single parameter AMC. Evaporation and transpiration can be estimated from the soil moisture characteristics for the soil horizons and a knowledge of the growth patterns and moisture requirements of the plants.

Any hydrologic characteristic that is dependent on the geometry of the pore space will be changed by the disturbance of surface mining. If these characteristics are to be defined they must be defined in terms of the porosity that will exist or some parameter related to the porosity. The nomograph shown on Figure 3 is provided to assist in making estimates of porosity and related functions. This nomograph assumes a two-phase system of soil particles and water. Where three phases are present (soil, air, and water), appropriate corrections or adjustments should be made to the data or estimates. For example, when the total density is computed from the moisture content of a saturated paste, it is usually higher than the measured density because of air bubbles included in the paste. A similar source of error is involved in computation of specific gravity of soil particles from shrinkage limit and shrinkage ratio (ASTM (1958) Designation D426-39, paragraph 10).

Void ratios are used to control compaction of soil in engineering practices. The nomograph is useful in conversions between density data, porosities, void ratios, and saturated moisture contents. This nomograph can be constructed for any particle density.

The forces involved in erosion of soils are extremely complex and variable. Prediction of erosion rates from laboratory tests of physical properties of soils has not been successful. It is possible, however, to define relative susceptibility of soils to a given set of erosion forces by controlled tests (McQueen, 1961). For significant results, the erosion forces and the condition of the samples prior to and during the tests should simulate conditions expected in the field.

Three methods for determining soil erodibility have been combined in a laboratory test for defining the susceptibility of these soils to

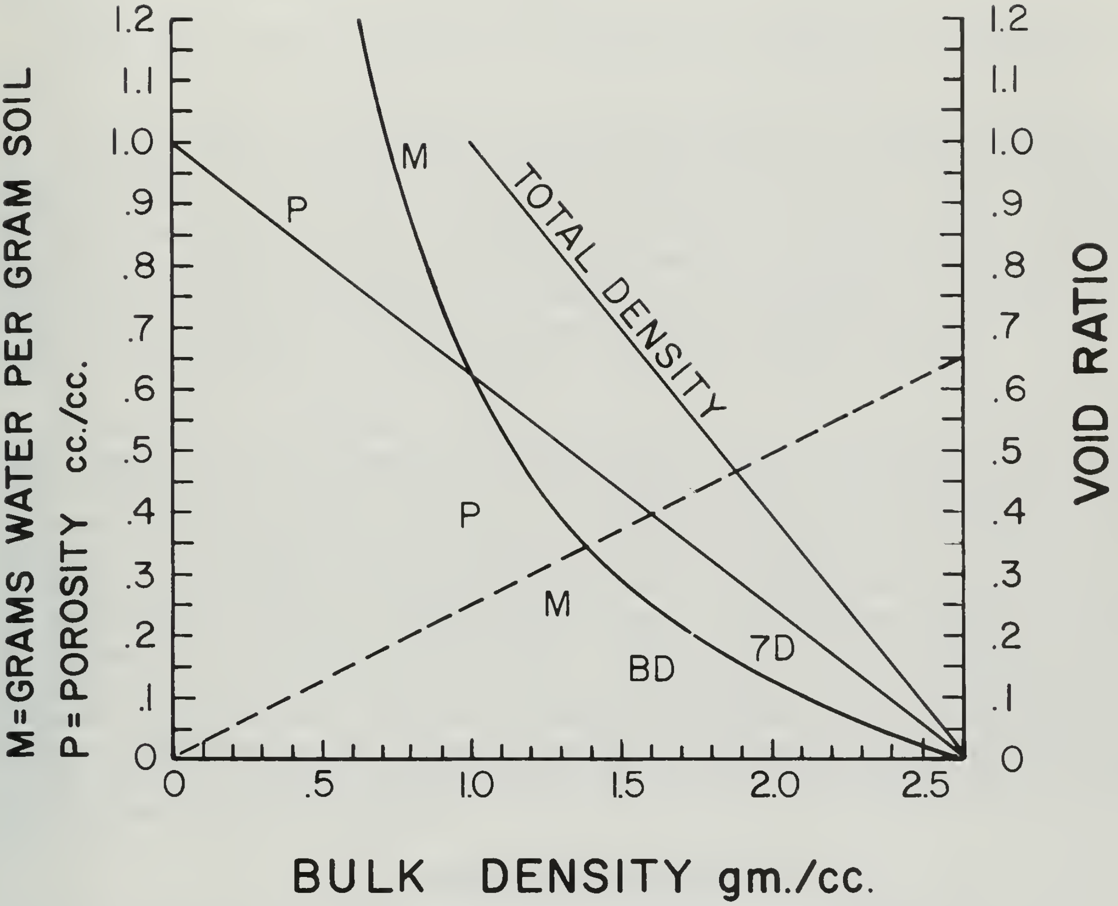


Figure 3 ----Nomograph for conversion between bulk densities, total densities, porosities, saturated moisture contents and void ratios.

erosion forces: a slaking test suggested by Winterkorn (1973), rotating cylinder methods (described by Masch et al., 1965, Akky and Shen, 1973; Arulanandan et al., 1973), and an erodibility factor (described by Wischmeier and others, 1958, 1959, 1965, 1969, 1971a, 1971b, and 1973) were based on measurements of grain size and other physical and chemical properties. This test constitutes a direct determination of the inherent erodibility of individual soil samples.

These data can be averaged and combined to predict the erodibility of the disturbed and mixed soils.

Actual erosion and sediment yield from soils will depend more upon the water available to transport the sediments than upon the erodibility (detachability) of the soils. Sand and silt particles are easily detached, therefore sandy soils test as highly erodible. Infiltration, however, may be high enough to adsorb all but extreme high intensity storms, so erosion and sediment production on sandy soils is usually low. Clay soils do not test as highly erodible because of their cohesiveness, but runoff is usually excessive, so erosion and sediment yields are high.

Vegetation diminishes erosion in three ways: (1) it intercepts raindrop impact, (2) it impedes overland flow, and (3) it binds soil particles together in a root network. The decrease in raindrop impact is proportional to the natural cover but the relationship is species dependent. Impedence of overland flow is influenced by topography, but it is controlled by quantities of vegetation. Grasses are extremely effective, but individual trees may have little effect. The binding effect of roots is included in the erodibility test. Disturbed soils may require additional protection from erosion, while vegetation is being reestablished. Overland flow can be controlled by surface treatments such as contour furrowing. Interception of raindrop impact can be provided by mulches placed on the surface and the binding effect of roots can be simulated by incorporating mulch into the soil.

Sample computations

The data from individual samples presented in this report can be combined and averaged in various ways to predict how the soils will perform when mixed by the mining procedure. Data from sampling sites Nos. 4 and 6 are used here as an example (Figure 4). Similar computations can be made for other material that may be available.

Assuming that for efficient mining operations it would be advantageous to mix the surface soils from sampling sites 4 and 6, the probable characteristics of the mixture can be computed by averaging the data from individual samples or by using depth-weighted profile averages. The weighted average AMC is computed as: $[(0.597)(10)+(0.213)(15)]/25=0.367$. The weighted average SMC is 0.429. The soil moisture characteristics for profiles 4 and 6 and the mixed profile are shown in Figure 4. The

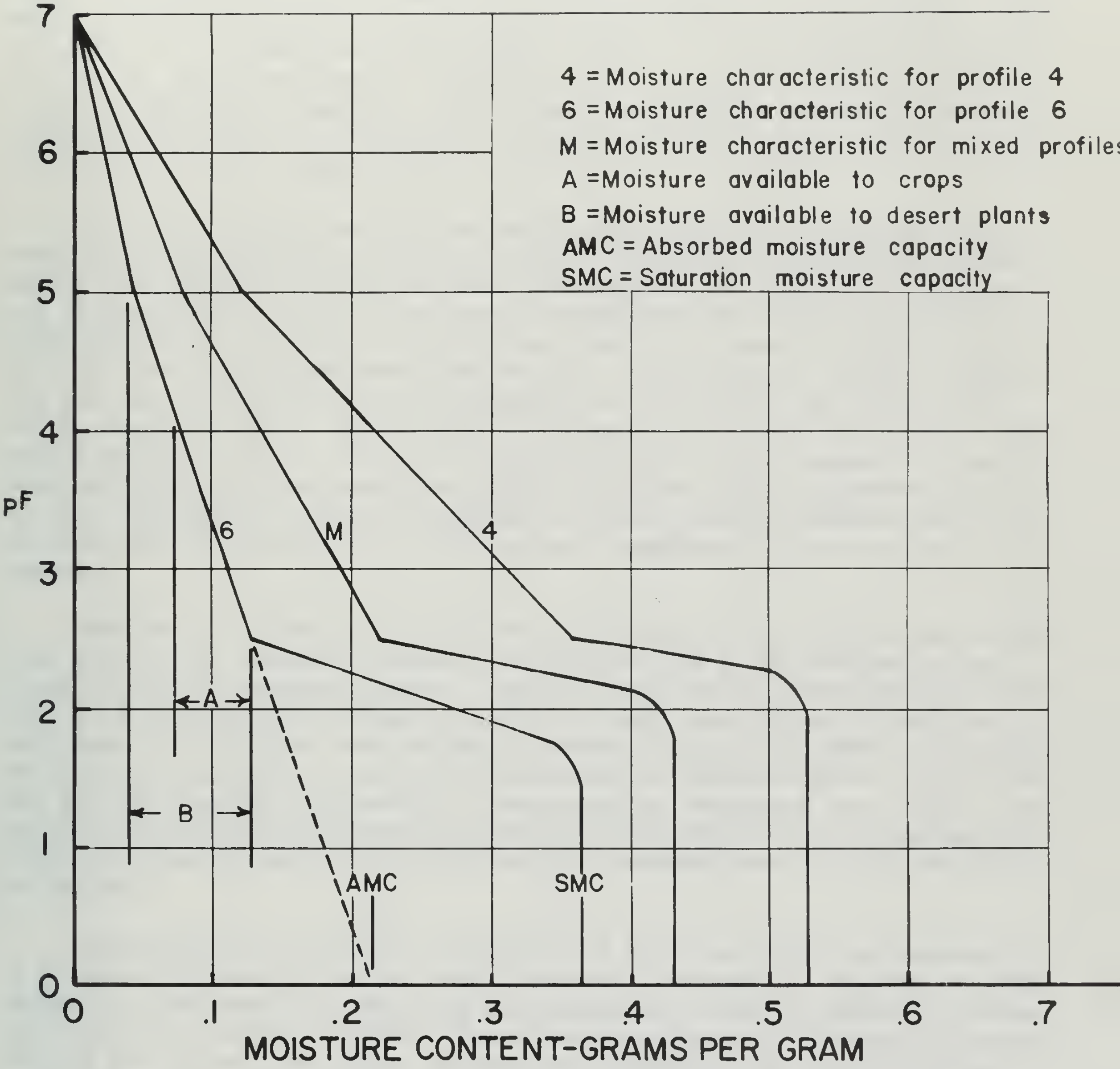


Figure 4- Soil moisture characteristics for the soils at sites 4 and 6 and the mixture of the two soils.

adsorbed film segments were plotted by using the intercepts (0, 6.25) and (AMC, 0) and drawing the lines between pF 2.5 and 5. The capillary segment is drawn by using the capillary limit (0, 2.9) and the field capacity value on the adsorbed film segment (FC, 2.5). The mean SMC value is plotted at pF 0 and a short vertical segment is drawn which is connected with the capillary segment. The tightly adsorbed or structured segment is drawn by connecting the top of the adsorbed film segment at pF 5 with the zero moisture content value at pF 7.

Moisture use between any two stress values can be estimated from the moisture characteristic graph or it can be computed. Where both stress values are included in the adsorbed film segment ($2.5<pF<5$) the moisture use $(\Delta M)=(AMC/6.25)(\Delta pF)$. The moisture available for use between field capacity and the wilting point for the mixed soil would be $(0.367/6.25)(4.1.7-2.5)=0.0998$ gram per gram of soil. The volume or depth of water use per unit of soil depth will depend upon the density or voids ratio of the emplaced soil. If the soil is emplaced at a void ratio of 1, the bulk density would be 1.34 (from Figure 3), and the volume of moisture available for use would be $(1.34)\ (0.116)=0.1337$ centimeter of water per centimeter of soil. Moisture of the capillary segment will only be available for use by plants during and immediately after recharge events.

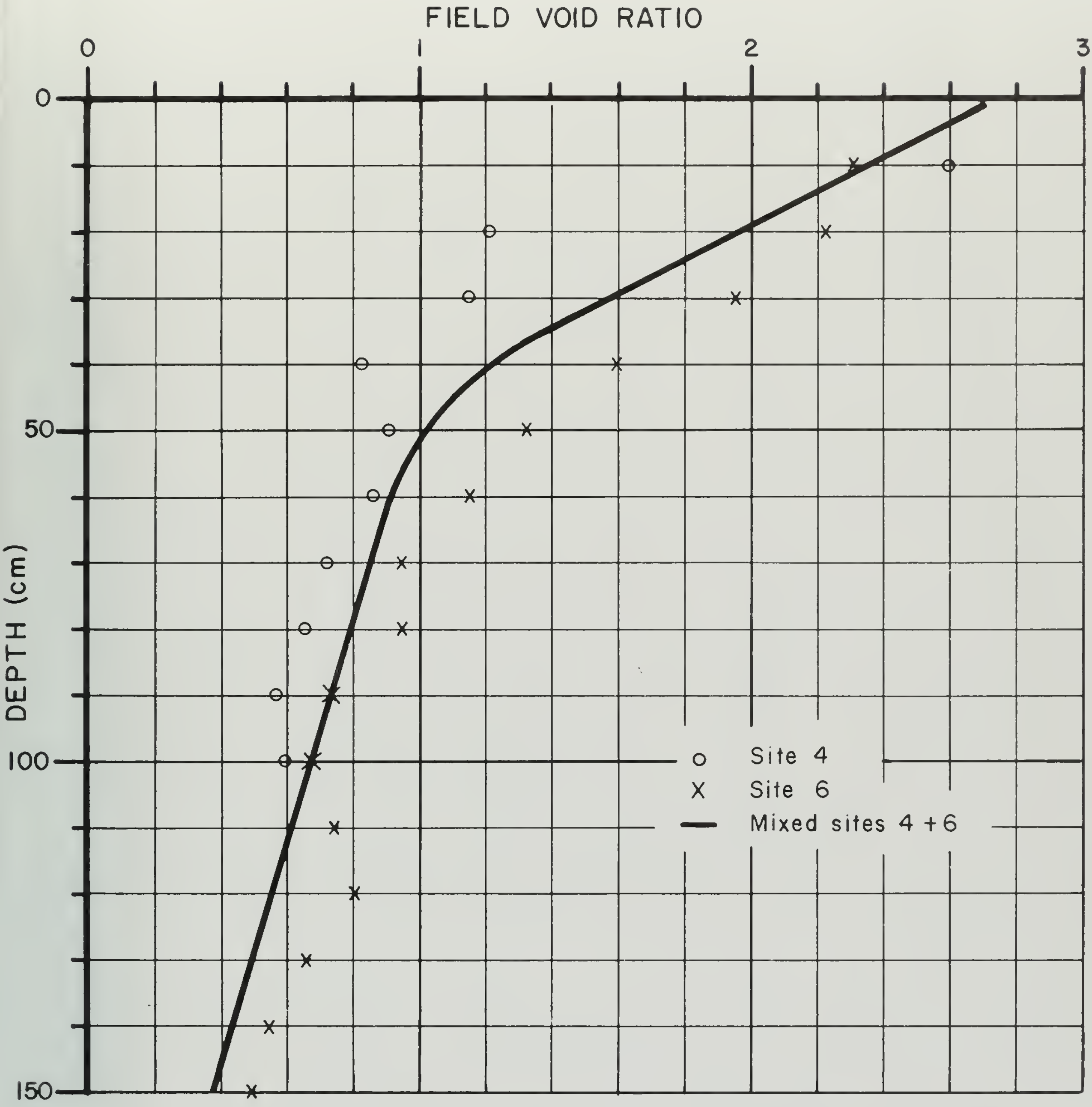
Analyses of moisture utilization in natural soil profiles have shown that all of the available moisture storage in the 1 (A) horizon is utilized during the growing season. In the 2 (B) horizon approximately one-half of the available storage capacity is used, and in the 3 (B-2) horizon about one-fifth of the available storage capacity is used. Using the mixed soil from sites 4 and 6 and assuming that horizon depths of 40, 90, and 150 centimeters will develop, the expected moisture use would be $(0.134)(40)+(0.134)(50/2)+(0.134)(60/5)=5.36+3.35+1.61=10.32$ centimeters. Similar estimates can be made for various combinations of soils and horizon depths.

Estimates can be made of the depth of soil that will be recharged by a given storm event. Assume that a surface treatment is applied so that runoff is prevented and that the soil moisture stress or moisture content preceding the storm is known. The moisture content of the wetted portion of the profile will be field capacity so compute ΔM between antecedent conditions and field capacity. Next multiply ΔM by the bulk density of the soil and divide the total storm amount by this product. Computations for the mixed soil for sites 4 and 6 are: $\Delta M = (0.367/6.25)(4.14-2.5) = 0.0963$. Using depth-weighted antecedent bulk density of 1.41 $(0.0963)(1.41) = 0.136$ cc/cc, a 6-centimeter storm would wet the profile to a depth of $6/0.136 = 44.1$ centimeters.

The storage capacity of the surface treatment required to prevent runoff can be estimated by subtracting the infiltration rate (IR) from expected storm intensities. The average IR for site 4 is 1.129 cm/hr,

site 6 is 0.735, and the depth weighted average is 0.697 cm/hr. A 2-hour storm with an average intensity of 3 cm/hr would require (3-0.697) 2=4.61 cubic centimeters per square centimeter of soil surface.

The geometry of the pore space within soils will be altered by mining operations and it can be controlled, within limits, by compaction procedures during shaping of the replaced soils. Additional changes in pore geometry will occur during the revegetation process because of wetting and drying or freezing and thawing cycles. Estimates can be made of the probable porosity relationships for mixed profiles by plotting the field void ratios (FVR) against sample depths and sketching an average curve (see Figure 5). This method is suggested because porosity is influenced more by position in the soil profile than by soil physical properties.



Variation in void ratio with depths at sites 4 & 6 and the probable void ratio–depth curve for the mixed soils after reclamation.

FIGURE 5

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